Р

УДК 622.831+622.224.001.57

V. N. Pavlysh, G. I. Turchanin, O. A. Tikhonova
Donetsk National Technical University
83001, Donetsk, Artyoma str., 58

MODIFICATION OF COMPUTER METHODS OF PRESENTATION AND ANALYSIS OF GEOTECHNICAL INFORMATION

В. Н. Павлыш, Г. И. Турчанин, О. А. Тихонова
Донецкий национальный технический университет
83001, г. Донецк, ул. Артема, 58

МОДИФИКАЦИЯ КОМПЬЮТЕРНЫХ МЕТОДОВ ПРЕДСТАВЛЕНИЯ И АНАЛИЗА ГЕОТЕХНИЧЕСКОЙ ИНФОРМАЦИИ

В. М. Павлиш, Г. І. Турчанін, О. А. Тихонова
Донецький національний технічний університет
83001, м. Донецьк, вул. Артема, 58

МОДИФІКАЦІЯ КОМП'ЮТЕРНИХ МЕТОДІВ ПОДАННЯ ТА АНАЛІЗУ ГЕОТЕХНІЧНОЇ ІНФОРМАЦІЇ

The article considers the problem of improvement of presentation ways and mathematical analysis methods of geotechnical information about mine rock massif state for computer support of decision on mine development systems and functional providing of mine workings.
Key words: information, method, analysis, geotechnology, decision, algorithm.

В статье рассматривается задача совершенствования способов представления и методов математического анализа геотехнической информации о состоянии массивов горных пород для компьютерной поддержки принятия решений по выбору систем разработки и обеспечения работоспособности горных выработок.
Ключевые слова: информация, метод, анализ, геотехнология, решение, алгоритм.

У статті розглядається задача вдосконалення способів подання і методів математичного аналізу геотехнічної інформації про стан масивів гірських порід для комп'ютерної підтримки прийняття рішень по вибору систем розробки і забезпечення працездатності гірничих виробок.
Ключові слова: інформація, метод, аналіз, геотехнологія, рішення, алгоритм.

Actuality of the paper. On all of the stages of the mining enterprises activity (creation of projects, choice of the development systems, providing of stability of the mountain workings and methods of their abandoning) the major base of decision-making belongs to the state information of mountain rock massifs. In modern conditions the state of massif is presented in the form of large files containing the results of measurements, therefore the storage and processing of such information is impossible without computer technologies. In this connection the improvement of methods of presentation and analysis of measurement results, storing in a database, is an actual problem.

Statement of the problem. As the coal industry develops and the complex of assigned tasks increases, the problem of processing of more considerable amount of various state information of rock massifs becomes more prominent. Meanwhile, in a number of cases, the traditional methods do not provide sufficiently reliable results; this determines the problem of modification of the applied mathematical methods.

Theoretical analysis of the research. In the informative aspect the rock geomechanics solves a number of complex tasks [1].

1. Analysis of change regularity of the deflected mode of enclosing rocks in the process of mining.

2. Explanation of technological processes and parameters of minerals excavation.

3. Control of rock pressure, purposeful stress redistribution, deformation, destruction and consolidation of rock massifs, i.e. control of the deflected mode of rock massif in the process of mining.

As a result of multistage researches we have large databases used for explanation of process diagrams and parameters of mining; choice of development systems and determination of their elements; development of rational methods and schemes of rock pressure control in the process of surface and underground mining, as well as recommendations for the optimal timbering, maintenance and security of the mining, and protection of other objects from the harmful influence of mining.

The purpose of the paper is the development of method of «moving averages» for the processing of numeric data on the state of rock massifs, which is directed at the elimination of disadvantages of the widely used method of «statistical average».

The research task is an explanation of modification of the method of «moving averages», allowing to reduce the time delay of presentation of results and to decrease the fluctuations of averaging results.

The principal content of the paper. Nowadays the geophysical methods of stress measurement are widely used for rock massifs; they are based on interconnection with the natural stress state of parameters of different artificial physical fields. They include ultrasonic (impulsive seismic), radiometric, electrometric, magnetic, seismic-acoustic (sound-ranging) methods.

Modern conception of monitoring of some processes or phenomena, including the analysis of information about the state of rock massifs, comprises the followings obligatory components:

− priority development of mathematical or other models of the controlled processes;
− choice and determination of the priority controlled parameters;
− measurement of these parameters in natural conditions;
− comparison of determined and measured values in order to make necessary corrections to the accepted models;
− assessment of the modern state of the controlled object by comparison of the measured and predicted critical values of the observable parameters;

− development of technical measures of mining efficiency and safety;

− control of realization of the developed technical measures and their modifications.

Any controlled process corresponds to the analysis and processing of time series obtained by measuring the observable values.

Analyzed observable values are interpreted as a sum of systematic (trend) and random cyclic components (noise). There is no «automatic» method of finding trends in time series. However if trend is monotonous (steadily increasing or decreasing), the analysis of such series is not difficult. If time series contain a considerable error, the first step of trend selection is the smoothing. Smoothing always includes some method of local data averaging, when unsystematic components annul each other. The most general method of smoothing is moving average, when every term of series is replaced by weighed or unweighted average m of neighboring terms, where m is a width of «window».

However the instruments of time series analysis, based on the algorithms of moving average, have essential faults, which result in the decline of effectiveness:

− time delay of averaging results relative to the elements of numerical series by the value m/2, where m is a value of averaging time window;

− relatively high degree of fluctuation of averaging results, which poorly depends on the value m;

− influence of linear frequency distortions as a result of essential nonlinearity of amplitude-frequency response (AFR) of moving average algorithms [2];

− linearization of nonlinear trends, by selection of these trends with certain displacement [3].

In order to avoid the mentioned faults we propose a new algorithm of the so-called «Synthetic moving average (SMA)».

A time delay of averaging results is the consequence of phase delays of all spectral components of the selected trends. Phase-frequency response (PFR) of averaging algorithm provides a phase shift (time delay) of every spectral component characterizing the selected trend:

$$\tau_{ô}\left(f_{í} \right) = -\phi\left(f_{í} \right) / f_{í} ,$$

where: $\varphi\left(f_{н}\right)$ is PFR of averaging algorithm; and $f_{н}$ is normalized frequency.

Group delay, explaining the delay of a selected trend relatively to its real position by the value *m/2*, is given by the equation:

$$\tau_{гр} = -\frac{d\varphi\left(\overline{f_{н}}\right)}{d\,\overline{f_{н}}} ,$$

where $\overline{f_{н}}$ is the average value of the normalized frequency of power spectral density of the selected trends;

$\frac{d}{d\,\overline{f_{н}}}$ is the first derivative of the PFR averaging algorithm.

In this case it is reasonable to compensate $\tau_{гр}$, i.e. to reduce it to zero. Then the delay by value *m/2* will be eliminated. Unfortunately, complete compensation of $\tau_{гр}$ is impossible because of the properties of integral filtration. Partial compensation ($\tau_{гр} \approx 0$) is fully realized in practice by multiple data averaging of «forward-backward» time series. Thus, it is possible to compensate the time delay by complicating the averaging algorithm through introduction of additional algorithmic redundancy.

The research involves the traditional exponential moving average (EMA) algorithm. It was found that the use of multiple «forward-backward» EMA algorithms compensates not only $\tau_{гр}$ but also linearizes its PFR. The table 1 describes the algorithm of new averaging for m = 4.

Therein X_i is the levels of the observable time series. Value Q_i is the reports of the trend selected by the SMA. The backward averaging accumulates the time delay of averaging (group delay), which is compensated by reverse «forward» pass.

Combination of «forward-backward» passes helps to obtain the SMA values at the time satisfying the moment of existence of X_4 (it allows to realize an operating control).

Value α (coefficient of classic exponential averaging) is determined by

$$\alpha = \frac{2}{m+1}, \qquad (1)$$

where: *m* is the EMA period (moving window).

New SMA algorithm for calculation of coefficient α uses the fixed value *m* = 2 (the averaging effect is preserved, autocorrelation relations are minimized). This value differs from the real value of moving window *m*: α = 2 / 3.

Further, similar to the realization of any moving average algorithm, the level X_1 is truncated and new X_5 is added.

Table 1 – Synthetic moving average algorithm

X_i / Y_i	X_1	X_2	X_3	X_4
I	← $Q_4=Q_3+\alpha(C_1-Q_3)$ ↓	$Q_3=Q_2+\alpha(C_2-Q_2)$	$Q_2=Q_1+\alpha(C_3-Q_1)$	← $Q_1=C_4$
II	→ $Q_5=Q_4$	$Q_6=Q_5+\alpha(Q_3-Q_5)$	$Q_7=Q_6+\alpha(Q_2-Q_6)$	(Y_1) → $Q_8=Q_7+\alpha(Q_1-Q_7)$

The fig. 1 describes the logical scheme of realization of the synthetic moving average algorithm m=4 [4].

The fig. 2 demonstrates the assemblage of new proposed moving averages, characterized by different amount of passes *n*. As the value of averaging window *m* increases, the number of passes *n* grows. It results in insignificant curve delay from the real trends. The observed effect is bound by minimum linear frequency distortions and incomplete compensation of time delay.

The proposed SMA algorithm allows to minimize the known faults of traditional moving average algorithms (time delay and relatively high level of fluctuations of their results), as well as to considerably reduce their faults, related to linear frequency distortions and to the linearization effect of selected nonlinear trends.

At the same time, the SMA has a number of disadvantages (possibility of application of instruments only with multiplicity equal to four: m=4; 8; 12 and so on; considerable complications of algorithms; possibility to use only the traditional EMA algorithm for averaging).

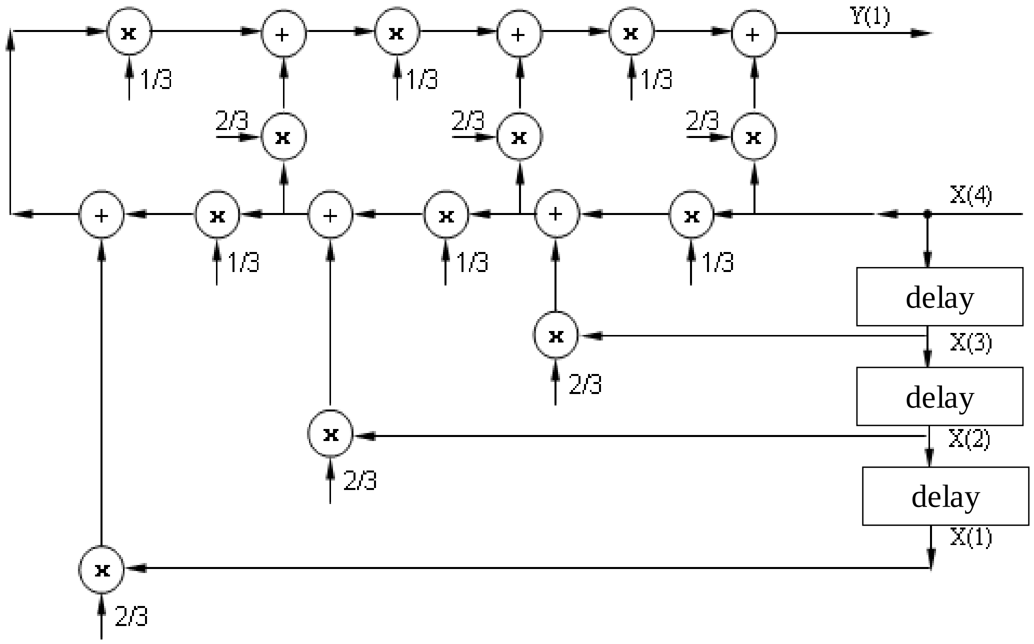

Figure 1 – Scheme of realization of algorithm, m=4

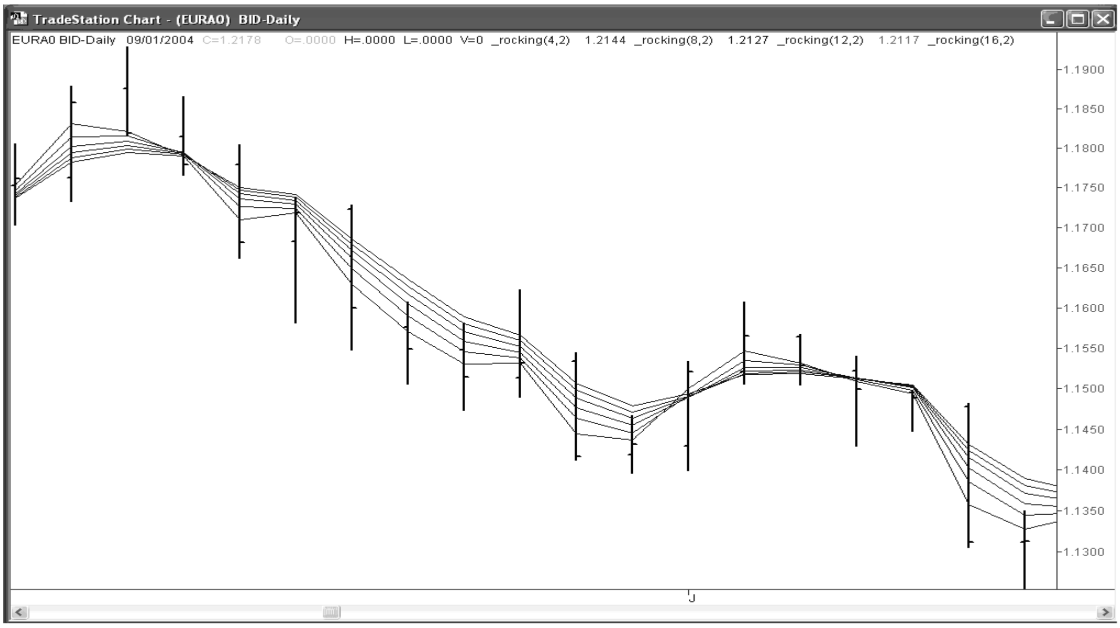

Figure 2 – Effect of multiple averaging through the realization of original moving average

Relying on the graphic approach the researcher can discriminate the followings moments: increasing trend, decreasing trend and disordered chaotic motion.

Qualitative assessment of the moving average method can be the index of total value of probability of «positive» signals on the trend.

Comparative analysis of probabilistic values of generation of «positive» and «negative» signals of classic and synthetic moving average algorithms [4] as well as of indicators, plotted on their basis, helps the user to decide on the methods of trend determination.

Generalized analysis of the dynamics changes of discrete series results in their classification into two states: trend presence and chaos. Analysis of the signals received by the indicator also results in their classification into two states: correct and error signals.

Let us denote the correct signal probability as $P_{correct}$, and the error signal probability as P_{error}.

Correct signal is the global and uniting event of smaller event series forming a divisible group, as well as the error signal is the global and uniting event of opposite smaller event series. Consequently, the probability $P_{correct}$ comprises the sum of probabilities of elementary events forming a divisible group of correct signals.

Applying the ideal indicator we have $P_{correct} \to 1$, and $P_{error} \to 0$. In practice, we follow the next rule: $P_{correct} \to \max$, and $P_{error} \to \min$.

Calculation of probabilities:

$$P_s = N_s / N_{total},$$

$$P_{\text{no\_b}} = N_{\text{no\_b}} / N_{total}, \; P_{\text{no\_f}} = N_{\text{no\_f}} / N_{total}$$

$$P_{no\_s} = N_{no\_s} / N_{total}, \qquad P_{\text{b}} = N_{\text{b}} / N_{total},$$

where:

N_{total} – total amount of trend and trendless periods of discrete series

$$N_{total} = N_{inc} + N_{dec} + N_{flat}$$

N_{inc} – total amount of increasing trends;

N_{dec} – total amount of decreasing trends;

N_{flat} – total amount of flats;

N_{s} – amount of signals indicating the true trend;

N_{no_s} – amount of skipped signals indicating the true trend;

N_{no_b} – amount of skipped signals indicating the false trend;

N_{b} – amount of signals indicating the false trend;

N_{f} – amount of considered periods of chaos;

N_{no_f} – amount of skipped periods of chaos;

The depth of possible prognosis depends on dispersion of reports of the selected trends relative to their real values. The less the selected trend is variable, the more precise and long period of time the statistical prognosis is carried out. The optimal moving average algorithm is the algorithm with minimal dispersion.

Let us consider the algorithms of signal formation (presence and completion of trend).

Variant 1.

Generation of signals by 1-line moving average is realized through the following general rule:

$$\begin{cases} \text{increase\_trend}, & \text{if } MovAver(m)_i = X_i, \; MovAver(m)_{i+1} < X_{i+1} \\ \text{decrease\_trend}, & \text{if } MovAver(m)_i = X_i, \; MovAver(m)_{i+1} > X_{i+1} \end{cases}$$

where m is the value of moving window;

MovAver is one of the proposed moving average algorithms;

X is the numeric discrete series;

Variant 2.

Generation of signals by crossing of 2 lines of moving averages is realized through the following general rule:

$$\begin{cases} \text{increase\_trend}, & \text{if } MovAver(m1)_i = MovAver(m2)_i, \\ & MovAver(m1)_{i+1} > MovAver(m2)_{i+1},\ MovAver(m1)_i < X_i \\ \text{decrease\_trend}, & \text{if } MovAver(m1)_i = MovAver(m2)_i, \\ & MovAver(m1)_{i+1} < MovAver(m2)_{i+1},\ MovAver(m1)_i > X_i \end{cases}$$

where *m1*, *m2* are the values of moving windows of fast and slow moving average lines, $m1 < m2$;

MovAver is one of the proposed moving average algorithms;

X is the numeric discrete series;

Variant 3

Rules of generation of signals for the classic MACD indicator:

$$\begin{cases} \text{increase\_trend}, & \text{if } EMA(m)_i = MACD_i > 0, \\ & MACD_{i+1} < EMA(m)_{i+1} \\ \text{decrease\_trend}, & \text{if } EMA(m)_i = MACD_i < 0, \\ & MACD_{i+1} > EMA(m)_{i+1} \end{cases}$$

Rules of generation of signals for the synthetic MACD indicator:

$$\begin{cases} \text{increase\_trend}, & \text{if } SMA(m)_i = MACD\_S_i > 0, \\ & MACD\_S_{i+1} < SMA(m)_{i+1} \\ \text{decrease\_trend}, & \text{if } SMA(m)_i = MACD\_S_i < 0, \\ & MACD\_S_{i+1} > SMA(m)_{i+1} \end{cases}$$

where $m = 8$;

$$MACDi = EMA(12)i - EMA(28)i;$$

$$MACD\_Si = SMA(12)i - SMA(28)i;$$

These data are selected by taking into account the properties of the SMA algorithm (applied only to the moving windows multiple of 4).

The research involves discrete series obtained by measuring the deflected mode of enclosing rocks.

Data analysis indicates:
increasing trends - 20;
decreasing trends - 18;
state of «chaos» - 9.

Total amount of the «special» periods is 47. The problem has separate solutions for decreasing and increasing trends. The ideal maximal value $Ps_{increase}$ = 0,426, $Ps_{decrease}$ = 0,383. Value $P_{no\_b\ increase}$ = 0,383; $P_{no\_b\ decrease}$ = 0, 426 and P_{no_f} = 0,191 (for both increasing and decreasing trends).

Considering the theory of equal possibilities, each of six probabilities has $\frac{1}{6} \approx 0.1667$ or $\frac{1}{3} \approx 0.3333$ is for every divisible group consisting of two inconsistent events.

In order to analyze the obtained results we introduce the following assessments:

Choice of the moving average algorithm with the following value $P_{correct}$:

optimal algorithm is $P_{correct}$ >= $\frac{1}{3}$;

less optimal algorithm is $P_{correct}$ >= $\frac{1}{6}$;

nonoptimal ones are all other cases;

The table 1 shows the data obtained by the calculation of probabilities forming P_{error} and $P_{correct}$. The bottom line reflects the results of dispersion calculations.

We use the assertion of the optimal algorithm with $P_{correct}$ >= $\frac{1}{3}$ as a working hypothesis and test it by the Bernoulli theorem [5]:

$$P\left\{\left|\frac{m}{k} - p\right| \geq \varepsilon\right\} \leq \frac{p(1-p)}{k\varepsilon^2}.$$

where m is a number of occurrence of event A in k independent (pair) tests,
p is the probability of occurrence of event A in each of the tests;

$$\varepsilon = \left|\frac{m}{k} - Pcorrect\right|.$$

The table 2 shows the results of calculations made in the Microsoft Excel. Calculations are carried out for the signals generated on ascending trends.

Table 2 – Calculation of probabilities and dispersion.

Probability	Making probabilities	MA 1 line	EMA 1 line	SMA 1 line	MA 2 line	EMA 2 line	SMA 2 line	MACD	MACD_S	CCI	CCI_S
Pcorr	P_s	0,319	0,298	0,362	0,17	0,192	0,404	0,362	0,404	0,234	0,277
	P_{no_b}	0,277	0,234	0,192	0,298	0,362	0,234	0,319	0,213	0,340	0,298
	P_{no_f}	0,064	0,085	0,000	0,149	0,192	0,021	0,149	0,021	0,128	0,064
Perr	P_{no_s}	0,106	0,128	0,064	0,255	0,234	0,021	0,064	0,021	0,192	0,149
	P_b	0,106	0,149	0,192	0,085	0,021	0,149	0,064	0,17	0,043	0,082
	P_f	0,128	0,106	0,192	0,043	0,000	0,17	0,043	0,17	0,064	0,128
Dispersion		10,87	8,14	4,118	53,5	41,44	3,42	12,88	2,84	44,91	23,23

The table 3 shows the results of calculations on the basis of inequality of the Bernoulli theorem.

Table 3 – Results of calculations of inequality of the Bernoulli theorem

	SMA 1 line	EMA 1 line	MA 1 line		SMA 2 lines	EMA 2 lines	MA 2 lines		MACD_S	MACD		CCI_S	CCI
Ascend. trend													
m=	17	14	15		19	9	8		19	17		13	9
k=	47	47	47		47	47	47		47	47		47	47
p=	0,426	0,426	0,426		0,426	0,426	0,426		0,426	0,426		0,426	0,426
m/k=	0,3617	0,2979	0,3191		0,4043	0,1915	0,1702		0,4043	0,3617		0,2766	0,1915
eps=	0,0643	0,1281	0,1069		0,0217	0,2345	0,2558		0,0217	0,0643		0,1494	0,2345
right part =	1,258	0,317	0,456		11,003	0,095	0,080		11,003	1,258		0,233	0,095
	RIGHT	RIGHT	RIGHT		RIGHT	UNRIGHT	UNRIGHT		RIGHT	RIGHT		RIGHT	UNRIGHT

Conclusions. As a result of the researches we substantiate the new algorithm of processing of trend state information of the rock massifs allowing to minimize the known faults of the traditional moving average algorithms (time delay and relatively high level of fluctuations of their results), as well as to considerably reduce their faults relative to the linear frequency distortions and to the effect of linearization of the selected nonlinear trends.

References

1. The control of mining rock massive stage / S. S. Grebyonkin, V. N. Pavlysh, V. L. Samoylov, Y. A. Petrenko. – Donetsk : “VIK”, 2010.-193p,
2. Smirnov A. The exclusion of trends with minimal deviation / A. Smirnov, O. Tikhonova // Science works of DonNTU. – Series «Informatics, cybernetics and computer technics». – Edition 8. – Donetsk, 2007. – P. 256-261.
3. Tikhonova O. A. The new class of synthetic indicators / O. A. Tikhonova // The materials of second international science-technical conference. – DonNTU, 2007. – P. 271-277.
4. Tikhonova O. A. The optimum of algorithm of synthetic slide middle / O. A. Tikhonova // Science works of DonNTU. – Series «Informatics, cybernetics and computer technics». – Edition 12. – Donetsk, 2010. – P. 152-155.
5. Tikhonova O. A. The comparison analysis of algorithm of synthetic slide middle with classic algorithms of slide middle by point of digital filte / O. A. Tikhonova // Science works of DonNTU. – Series «Informatics, cybernetics and computer technics». – Edition 9. – Donetsk, 2008. – P. 287-291.
6. Pavlysh V. N. Mathematical modeling of the functioning of the specialized vehicles such as convective / V. N. Pavlysh, E. V. Perinskaya // Problems of Artificial Intelligence. – 2015. – № 0 (1). – P. 89-98.

Список литературы

1. Управление состоянием массива горных пород / С. С. Гребенкин, В. Н. Павлыш, В. Л. Самойлов, Ю. А. Петренко.– Донецк: «ВИК», 2010.– 193 с.
2. Смирнов А. Выделение трендов с минимально возможной колеблемостью / А. Смирнов, О. Тихонова // Научные работы ДонНТУ. – Серия «Информатика, кибернетика и вычислительная техника». – Выпуск 8. – Донецк, 2007. – С. 256-261.
3. Тихонова О. А. Новый класс синтетических индикаторов / О. А. Тихонова // Материалы второй международной научно-технической конференции. – ДонНТУ, 2007. – С. 271-277.
4. Тихонова О. А. Оптимизация алгоритма синтетического скользящего среднего / О. А. Тихонова // Научные труды ДонНТУ. – Серия «Информатика, кибернетика и вычислительная техника». – Выпуск 12. – Донецк, 2010. – С. 152-155.

5. Тихонова О. А. Сравнительный анализ алгоритма синтетических скользящих средних с классическими алгоритмами скользящих средних с точки зрения цифровой фильтрации / О. А. Тихонова // Научные работы ДонНТУ, серия «Информатика, кибернетика и вычислительная техника». – 2008. – Выпуск 9. – С. 287-291.
6. Павлыш В. Н. Математическое моделирование процессов функционирования специализированных аппаратов конвективного типа / В. Н. Павлыш, Е. В. Перинская // Проблемы искусственного интеллекта. – 2015. – № 0 (1). – С. 89-98.

RESUME

V. N. Pavlysh, G. I. Turchanin, O. A. Tikhonova

The Modification of Computer Methods of Presentation and Analysis of Geotechical Information

Background: On all of the stages of the mining enterprises activity (creation of projects, choice of the development systems, providing of stability of the mountain workings and methods of their abandoning) the major base of decision-making belongs to the state information of mountain rock massifs. In modern conditions the state of massif is presented in the form of large files containing the results of measurements, therefore the storage and processing of such information is impossible without computer technologies. In this connection the improvement of methods of presentation and analysis of measurement results, storing in a database, is an actual problem.

Materials and methods: The article considers the problem of improvement of presentation ways and mathematical analysis methods of geotechnical information about mine rock massif state for computer support of decision on mine development systems and functional providing of mine workings.

Analyzed observable values are interpreted as a sum of systematic (trend) and random cyclic components (noise). There is no "automatic" method of finding trends in time series. However if trend is monotonous (steadily increasing or decreasing), the analysis of such series is not difficult. If time series contain a considerable error, the first step of trend selection is the smoothing. Smoothing always includes some method of local data averaging, when unsystematic components annul each other. The most general method of smoothing is moving average, when every term of series is replaced by weighed or unweighted average m of neighboring terms, where m is a width of "window".

However the instruments of time series analysis, based on the algorithms of moving average, have essential faults, which result in the decline of effectiveness.

Results: In order to avoid the mentioned faults we propose a new algorithm of the so-called «Synthetic moving average (SMA)».

The proposed SMA algorithm allows to minimize the known faults of traditional moving average algorithms (time delay and relatively high level of fluctuations of their results), as well as to considerably reduce their faults, related to linear frequency distortions.

Conclusions: As a result of the researches we substantiate the new algorithm of processing of trend state information of the rock massifs allowing to minimize the known faults of the traditional moving average algorithms (time delay and relatively high level of fluctuations of their results), as well as to considerably reduce their faults relative to the linear frequency distortions and to the effect of linearization of the selected nonlinear trends.

The article entered release 29.02.2016.