По-п’яте, розвиток відповідальності студентів може бути ефективним за умови забезпечення системної цілісності навчально-виховного процесу та його чіткої практичної спрямованості. Важливими його складниками виступають виконання студентами реальних курсових і дипломних робіт на замовлення конкретних організації, їх спрямування на розв’язання проблем функціонування і розвитку цих організацій.

По-шосте, для формування відповідальності майбутніх фахівців з управління проектами вкрай важливою є належна організація вивчення курсу з поведінкових компетенцій, системне застосування при цьому активних методів навчання та інноваційних педагогічних технологій.

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MODIFIED MOVING-AVERAGE METHOD IN PROBLEMS OF SHORT-TERM FORECASTING OF TECHNICAL AND ECONOMIC INDICATORS IN HIGH-TECHNOLOGY ENTERPRISES

This paper proposes a modified moving average method. The basis of the method is to find an effective average estimator on the basis of moving that consists of some subset of the elements of the average series. To improve accuracy of the obtained forecast values the averages test for efficiency at each step of moving is done by the resampling method. This method is actively used in technical and economic analysis, as it has a profound statistical justification. The obtained forecast error values are acknowledged as possessing "satisfactory accuracy" and "good accuracy". Accordingly, the modified method has advantages over other modifications of the moving average method. In future studies of the proposed method in different time series, for example, with so-called "suspicious", "outlier" values the new results can be obtained.

Keywords: short-term forecasting, moving average method, resampling method.

Problem definition. State of technical and economic indicators of successful high-tech companies with well approved production processes and stable product orders on hand can be characterized by stationary (substationary) time series.

For short-term forecasting of such indicators the moving average method and a number of its modifications is widely used. The great popularity of this method is explained with the simplicity of its implementation as well as the fact that the moving average is essentially a mathematical expectation which is the base factor in statistics. The mathematical expectation is the most probable value of the analyzed indicators (parameters) and has a profound theoretical justification in the form of the law of large numbers and the central limit theorem.

However, this method has several disadvantages one of which is that the average value being the estimate of the mathematical expectation is sensitive to demonstrations of volatility (variability) of time series. It can be expressed in shifting and low effectiveness of such assessments.

Analysis of publications and recent researches. Analysis of a number of publications devoted to the short-term forecasting methods [1, 2, 3, 4, 5, and others] showed that a series of moving averages is described and implemented by now: Simple Moving Average (SMA) that is equal to the arithmetical average of the time series values in a definite period; cumulative moving average that is numerically equal to the arithmetical average of the series in the whole observation period; weighted moving average that is represented by the arithmetic progression with assigning certain "weights" by elements of a series; exponential moving average the basis for which is the smoothing coefficient that characterizes the rate of weight reduction of series elements.

There is all the class of adaptive moving averages that change their characteristics depending on the behavior of the analyzed parameters. For example, Kaufman's Adaptive Moving Average [7] which is based on the exponential moving average and uses the value of volatility to determine the optimum smoothing function.

Purpose of the work lies in the development and study of the modified moving average method which is characterized in that it is based on a search procedure of effective mean estimator on the base of moving that is composed of a subset of the elements of the series.

Statement of basic material. You can consider the following type of time series characterizing the certain features behavior of company activity $x(t_1)$, $x(t_2)$, $x(t_3)$, …, $x(t_i)$, …, $x(t_n)$.

Then, to obtain the forecast value in the form x_{n+1} at the moment t_{n+1} it is necessary to perform the following operation:

$$x_{f1} = x_{n+1} = \frac{x_1 + x_2 + x_3 + ... + x_i + ... + x_n}{n} \quad (1)$$

where n is a base of moving that is the number of previous values of the series that come under the averaging; x_f is a forecast value of the series.

To obtain the subsequent forecast values of the series at the moment t_{n+2}, t_{n+3}, ..., t_{n+k} (k is the forecast horizon, i.e. the number of time units for forecast), it is necessary to make a similar calculations:

$$x_{f2} = x_{n+2} = \frac{x_2 + x_3 + x_4 + ... + x_i + ... + x_{n+1}}{n},$$

$$x_{f3} = x_{n+3} = \frac{x_3 + ... + x_i + ... + x_{n+1} + x_{n+2}}{n},$$

…

$$x_{fk} = x_{n+k} = \frac{x_k + x_{k+1} + x_{k+2} + ... + x_{k+n-1}}{n} \quad (2)$$

The expressions (1) and (2) represent a process of "moving" through a time series with a base of moving n.

Thus, the obtained set of forecasts $\{x_{f,i}\}$, $i = \overline{1, k}$ represents the arithmetical (sample) averages.

Therefore, to improve the accuracy of the obtained forecast values it is reasonable to check the averages for efficiency at each step of moving. Methods of one of the modern trends of applied statistics, bootstrap methods, can be used with this view [6]. We can consider one of them known as the "resampling" of samples [6]. Let's suppose there is an original data sample:

$$x_1, x_2, x_3, ..., x_{k-1}, x_k, x_{k+1}, ..., x_{n-1}, x_n.$$

We can list the samples that can be obtained from the original:

$$x_2, x_3, ..., x_{k-1} \text{ etc.},$$

$$x_1, x_3, ..., x_{k-1} \text{ etc.},$$

$$x_1, x_2, x_4, ..., \text{ etc.},$$

$$x_1, x_2, x_3, ..., x_{k-1}, x_k, x_{k+1}, ..., x_{n-1}, x_n, \quad (3)$$

…

$$x_1, x_2, x_3, ..., x_k, x_{k+1}, ..., x_{n-1}, x_n,$$

$$x_1, x_2, x_3, ..., x_{k-1}, x_{k+1}, ..., x_{n-1}, x_n,$$

$$x_1, x_2, x_3, ..., x_{k-1}, x_k, ..., x_{n-1}, x_n,$$

$$x_1, x_2, x_3, ..., x_{k-1}, x_k, x_{k+1}, ..., x_n,$$

$$x_1, x_2, x_3, ..., x_{k-1}, x_k, x_{k+1}, ..., x_{n-1}.$$

Thus, n new (resampled) samples can be obtained with size (n–1) of each. The value of statistics we are interested in can be calculated for each of them (e.g. averages).

As applied to the problem the considered procedure (3) is as follows.

Let's suppose there is a sample of values of a series $X_0 = x_1, x_2, x_3, ..., x_i, ..., x_n$ with a size equal to the base of moving n. Let's determine the estimated mean by it $\bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i$. Dropping the element x_1 from the original sample X_0, we obtain the first modified sample $X_1 = x_2, x_3, ..., x_i, ..., x_n$ and $\bar{X}_1^* = \frac{1}{n-1}\sum_{i=1}^{n-1} x_i$. Then when we drop the element x_2 from X_0 and return the element x_1 to its sample, we obtain $X_2 = x_1, x_3, ..., x_i, ..., x_n$ and $\bar{X}_2^* = \frac{1}{n-1}\sum_{i=1}^{n-1} x_i$ and so on until n modified samples with a size (n–1) and n estimated sample means, $X_i^*, i = \overline{1, n}$..

Hereafter, in order to determine spread (effectiveness) of the obtained estimates $\overline{X}$ and $\overline{X}_i^*$ let's analyze the sum of residual differences squares (F) using the following formulas:

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$$F_0 = \sum_{i+1}^{n}(x_i - \overline{x})^2,\ F_1 = \sum_{i=1}^{n}(x_i - \overline{x_1^*})^2,...,$$
$$F_2 = \sum_{i=1}^{n}(x_i - \overline{x_2^*})^2,...,F_n = \sum_{i=1}^{n}(x_i - \overline{x_n^*})^2 \qquad (4)$$

In addition, we can determine the relative effectiveness of the considered estimates (G) with the use of such expressions:

$$G_1 = \frac{F_0}{F_1} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{\sum_{i=1}^{n}(x_i - \overline{x_1^*})^2},$$
$$G_2 = \frac{F_0}{F_2} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{\sum_{i=1}^{n}(x_i - \overline{x_2^*})^2},..., \qquad (5)$$
$$G_n = \frac{F_0}{F_n} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{\sum_{i=1}^{n}(x_i - \overline{x_2^*})^2}.$$

The subsequent choice of indicators for fulfillment of conditions $F_i \Rightarrow \min$ and $G_i \Rightarrow \max$ provides to obtain an estimated mean with a minimum spread value that is characterized by maximum efficiency.

This estimated mean will be taken as a forecast value. Let's consider a numerical example. Table 1 shows the time series $\{x_i\}$, i=1, m which characterizes the enterprise's profit performance in the period that is equal to m = 15 months; x_i is a monthly profit (mln. USD); base of moving is n = 10 values of the series $(x_1 \div x_{10})$; forecast horizon is k = 5 months; x_{act} is the actual value of the series; x_f^{ma} is forecast values obtained by the conventional moving average; x_f^{mma} is forecast values obtained by modified moving average.

Table 2 presents the results of using the bootstrap procedure of "resampling" of sample and subsequent estimation and finding effective mean estimators.

Table 1 –The values of the time series of the enterprise's profit performance

Values of the series	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
x_{act}	2	2	4	3	3	5	8	8	6	6	6	6	7	7	5
x_f^{ma}											7.8	7.6	7.6	7.5	7.5
x_f^{mma}											6.1	6.3	7	7	7.2

Table 2 –Resampling of the original time series and finding the effective mean estimators

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}						
2	2	4	3	3	5	8	8	6	6	$\overline{x} = 7{,}8$	$\overline{x}_1^* \div \overline{x}_{10}^*$	$F_0 = 267{,}5$	$F_1 \div F_{10}$	$(G_1 \div G_{10}) \cdot 100\%$	
	2	4	3	3	5	8	8	6	6		7.6		264		1.3
2		4	3	3	5	8	8	6	6		7.6		264		1
2	2		3	3	5	8	8	6	6		7.4		261		2.5
2	2	4		3	5	8	8	6	6		7.5		262.5		2
2	2	4	3		5	8	8	6	6		7.5		262.5		2
2	2	4	3	3		8	8	6	6		6.3		265.4		0.8
2	2	4	3	3	5		8	6	6		7.0		261		2.5
2	2	4	3	3	5	8		6	6		6.1		262.6		2
2	2	4	3	3	5	8	8		6		7.0		261		2.5
2	2	4	3	3	5	8	8	6			7.2		259		3.3

Table 3 –Typical values of forecasting errors and their interpretation [3]

e_t, %	Interpretation
<10	High forecast accuracy
10…20	Good accuracy
20…50	Satisfactory accuracy
>50	Unsatisfactory accuracy

To calculate the forecast errors et, performed by two methods, we can use the following expression [3]:

$$e_t = \left(\frac{1}{m} \sum_{i=1}^{m} \frac{(x_{act} - x_f)}{x_{act}} \right) * 100\%.$$

Then we have the following error values:

$$e_t^{ma} = \left\{ \frac{1}{5} \left(\frac{1,8}{6} + \frac{1,6}{6} + \frac{0,6}{7} + \frac{0,5}{7} + \frac{2,5}{5} \right) \right\} * 100\% = 24.4\%$$

$$e_t^{mma} = \left\{ \frac{1}{5} \left(\frac{0.1}{6} + \frac{0.3}{6} + 0 + 0 + \frac{2.2}{5} \right) \right\} * 100\% = 10.2\%$$

In accordance with Table 3 the obtained forecast error values are interpreted as "satisfactory accuracy" and "good accuracy" of forecast. This suggests that certain advantage of the proposed modified moving-average method in terms of more accurate forecasting values.

Conclusions. The moving-average method still takes an important place in technical and economic analysis, since it has a profound statistical justification. This obviously explains researchers' ongoing interest in it that is resulted in the appearance of numerous modifications of this method. The same aim is pursued in this work. It should be noted that new results can be obtained in deeper study of the proposed approach in different time series (for example, with so-called "suspicious", "outlier" values).

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