Determining the Effectiveness of Educational Impacts

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Визначення Ефективності Освітніх Впливів

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***Анотація*— У статті пропонується процедура визначення ефективності навчальних впливів методами сингулярного спектрального аналізу часових рядів. Модель запам'ятовування навчального матеріалу відповідає часовому ряду, який поновлений методом сингулярного спектрального аналізу (ССА). Розглянуто електронні методики вимірювань (е-метрики), які дозволяють чисельно проаналізувати ефективність роботи освітнього сайту.**

***Abstract*— The article proposes a procedure for determining the effectiveness of educational impacts using the time series singular spectral analysis methods. The model for memorizing the educational material corresponds to a time series reconstructed by the method of Singular Spectral Analysis (SSA). Electronic measurement methods (e-metrics) are considered that allow you to numerically analyze the effectiveness of the educational site.**

Ключові слова—дистанційне навчання, ефективність навчальних впливів, освітній сайт, сингулярний спектральний аналіз

Keywords—distance learning, the effectiveness of educational impacts, educational site, singular spectral analysis

I. INTRODUCTION

In connection with the transition to a credit-module system of study, due to the entry of Ukraine into the Bologna educational process, the educational process should become more structured and meaningful. In our time, the possibility of increasing the terms of training and the amount of training material is almost exhausted. Therefore, the problem of the differentiation of educational material can only be considered in unity with integration. In these conditions, assessment of the effectiveness of the learning process becomes particularly relevant. The ability to numerically assess the effectiveness of curricula involves the widespread use of mathematical methods and progressive information technologies, without which the problem of assessing the quality of education has no reasoned formalization.

To determine the effectiveness of educational impacts, the solution of the problem is proposed by methods of singular spectral analysis (SSA) of time series. The training material memorization model corresponds to the time series rebuilt by the SSA method. The considered electronic methods of measurements (e-metrics) allow to numerically analyze the effectiveness of the educational site.

II. SINGULAR SPECTRAL ANALYSIS

The process of meaningful memory is influenced by factors such as the structure of the material, the creation of associative connections between concepts, the frequency of the use of concepts [1,2]. But not only the logic of the presentation affects the memory of the material. It is known [3-8] that the process of assimilation and forgetting information can be provided in the form of a curve, which is depicted in Figure 1.

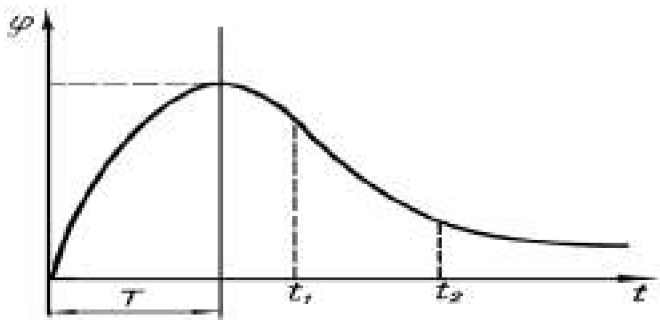

Fig. 1. The process of assimilation and forgetting information

The growing part of the curve reflects the process of perception, falling - forgetting. The time that corresponds to the largest amount of information and which is in memory (T) is the time of the end of the presentation of the material. Immediately after that, the process of forgetting begins.

With $t \to \infty$ the function $\varphi \to 0$, which corresponds to complete forgetting information for a sufficiently large period of time.

An important role in remembering is the periodic repetition of information that occurs during independent work, in laboratory and practical classes, as well as in the case of multiple references by lecturers to familiar material [9]. In order to increase the value φ at the end of the semester, educational effects should be distributed rationally throughout the course of study time, since the possibilities of their quantitative growth are rather limited. (Educational influences are lectures, practical or laboratory classes, independent work, reading of educational literature, that is, everything that impedes the process of "forgetting." Interestingly, first and foremost is the influence of active learning factors - classroom activities).

The Singular Spectrum Analysis (SSA) method is described in order to determine the effectiveness of learning effects in [10-14].

Let given time series $F=\{f_0,f_1, \dots ,F_{N-1}\}$. Separate additive components of the output series, such as the trend (smooth and slowly variable part of the row), different vibrational and periodic components, as well as the noise component, should be distinguished.

For a one-dimensional time series, the basic SSA method consists of the following steps [10-14]:

- the transformation of the output one-dimensional series into a multidimensional, which is described by a trajectory matrix;
- singular decomposition of the received trajectory matrix;
- grouping the members of the expansion;
- the next recovery (getting a trend).

Let's describe the steps in more detail.

Step 1. Execute the procedure of an embedding, that is, transforming the output one-dimensional series F into a sequence L - measurable vectors, the number of which, on condition, $K=N-L+1$, is:

$$X_i = (F_{i-1},\dots,f_{i+L-2})^T,\ 1 \le i \le K.$$

These vectors form a trajectory (hankel) matrix X of series F:

$$X = \begin{pmatrix} f_0 & f_1 & f_2 & \cdots & f_{K-1} \\ f_1 & f_2 & f_3 & \cdots & f_K \\ f_2 & f_3 & f_4 & \cdots & f_{K+1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_{L-1} & f_L & f_{L+1} & \cdots & f_{N-1} \end{pmatrix}.$$

Step 2. We obtain a singular expansion of a trajectory matrix of a series. Consider the matrix:

$$S = XX^T$$

Since S is positively semispecific, its own numbers are not negative. Let's denote through $\lambda_1,\dots, \lambda_L$ own numbers of the matrix S, taken in descending order ($\lambda \ge ,\dots, \ge \lambda_L \ge 0$) and through $U_1, \dots , U_L$. The orthonormal system of eigenvectors of the matrix S corresponding to these eigenvalues.

Get the function:

$$V_i = \frac{1}{\sqrt{\lambda_i}} \mathbf{X}^{\mathrm{T}} U_i, (i = 1,\dots,d)$$

where $d = max\{\ i,\ \ \lambda_i > 0\}$.

Ortogonal vectors V_i (so-called factor) are their own vectors of the matrix X^TX, corresponding to the same native numbers λ_i .

$\sqrt{\lambda_i}$ - singular numbers.

U_i a and V_i -left and right singular vectors of the matrix, respectively.

We obtain a singular expansion of a trajectory matrix:

$$X = X_1 + \dots + X_d \qquad (1)$$

Step 3. The grouping procedure divides the whole set of indices $\{1, \dots , d\}$ on m disjoint subsets $I_1 , \dots , I_m$.

Let

$$I = \{i_1 , \dots , i_p\}.$$

Then the resulting matrix X_I , which corresponds to the group I , defined as $X_I = Xi_1 + \dots + Xi_p$. Such matrices are calculated for $I_1 , \dots , I_m$, consequently, the decomposition (1) can be written in the grouped form:

$$X = X_{I1} + \dots + X_{Im}.$$

Procedure for selecting sets $I_1 , \dots , I_m$ and it is called a grouping of own triples

$$Q_i = (\sqrt{\lambda_i}, U_i, V_i).$$

Step 4. At the last step of the basic algorithm, each matrix of grouped expansion is translated into a new series of lengths N.

Let Y – matrix, size is LxK with elements.

$$y_{ij} : 1 \le i \le L,\ 1 \le j \le K.$$

Let

$$L^* = min\ (L,K),$$

$$K^* = max\ (L,K).$$

Let $z_{ij} = y_{ij}$, if $L < K$ and $z_{ij} = y_{ji}$ in other case.

Diagonal averaging translates the matrix Y in a row (g_0, , g_{N-1}) by the formula:

$$g_k = \begin{cases} \dfrac{1}{k+1}\sum_{j=1}^{k+1} z_{j,k-j+2} & \text{for } 0 \le k < L^* - 1; \\ \dfrac{1}{L^*}\sum_{j=1}^{L^*} z_{j,k-j+2} & \text{for } L^* - 1 \le k < K^*; \\ \dfrac{1}{N-k}\sum_{j=k-K^*+2}^{N-K^*+1} z_{j,k-j+2} & \text{for } K^* \le k < N. \end{cases}$$

That is, the elements of the matrix are averaged along the "diagonals" $i + j = k + 2$. Applying a diagonal averaging to matrices X_I, obtained at the stage of grouping, we arrive at the expansion of the initial series in the sum of m the series.

III. Description of the Research Process

For the research was selected the course "Computer Engineering", which is read at the Faculty of Engineering Ecology of Cities at the Kharkiv National University of Urban Management. O. M. Beketov [8, 15-19]. Testing was done twice a week during the semester. The total test was 35 times. Suppose that the time intervals between the tests are the same, so we will consider the time from 1 to 35. Studies using the SSA method have shown that the typical range of estimates can be divided into trends and noise, with the trend forming two first components (significance 95-98%), and noise - other (periodic components are also counted to noise).

Fig. 2 gives a series of ratings. We are exploring this time series is via the SSA method.

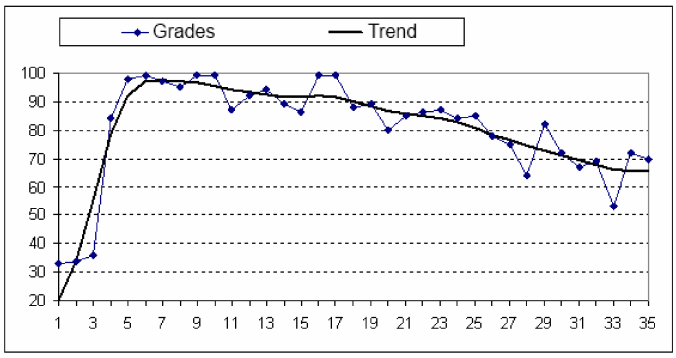

Fig. 2. Output range of estimates and its approximation

Get decomposition a series of three components (Fig. 3). Series can be separated in a row sites "remembering" and "forgetting".

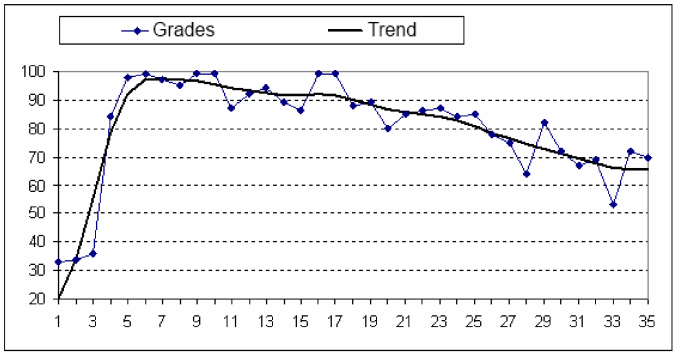

Fig. 3. Output range of estimates and its approximation

Note that in the area of "forgetting" the 2nd component is practically zero. By removing noise, we obtain the trend (approximation) of the output series as a time series, restored by the SSA method (Fig. 2).

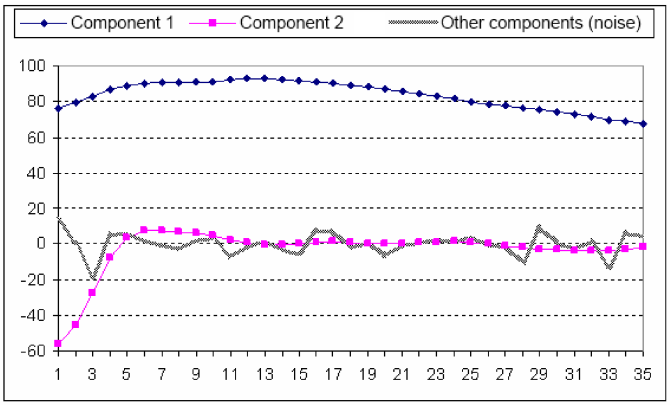

Fig. 4. Components of a row

During the first 4 weeks of the semester, students are studying two modules. Each module consists of 2 educational impacts (IE). Thus, students undergo 4 educational impacts:

- educational impact EI 1 (module 1): start time - 1;
- educational impact EI 2 (module 1): start time - 4;
- educational impact EI 3 (module 2): start time - 5;
- educational impact EI 4 (module 2): start time - 8.

We are interested in how EI 3 and EI 4 influence the knowledge of module 1, we have sampled students:

- set {1, 2, 3, 4} 83 persons - students who were present at all classes;
- set {1, 2, 3} 34 persons - students who attended all classes, except 4th;
- set {1, 2, 4} 27 persons - students who attended all classes except 3rd.

Average estimates for all three sets. The averaging effect - the noise is inverted, the accuracy of the approximation increases (Fig. 4).