Multidimensional monitoring of a streaming process

Aleksandr Pishchukhin
Orenburg state University, Department of Management and Computer Science in technical systems, 460018 Victory avenue 13, Russia
pishchukhin55@mail.ru

Abstract. The work is devoted to a multidimensional approach to the presentation of monitoring information about the streaming technological process, which is accompanied by a rather strict ratio of the durations of each of the operations. Usually these operations are quite a lot, and a small loss of time on one operation can be compensated for subsequent ones, the control of the duration of each of the operations is not very informative. In this case, it becomes relevant to consider the state of the technological process in a multidimensional space, the coordinates of the imaging points in which are the duration of each operation at a given time. Since the ratio of the durations of operations with each other must be fairly strictly conserved, it sets in a multidimensional space a ray of temporary operational norms. On the other hand, the sum of all operations determines the performance and so that it always lies on the hyperplane, for coordinates the scaling factors are determined. This hyperplane is called the equal contribution hyperplane. The difference between a real technological process and a normal one (deviation from the norm beam) can be estimated by two parameters determined in the plane of equal contributions: the distance of the imaging point from the intersection point of the norm beam and the plane of equal contributions and the angle of rotation of the beam to the imaging point relative to the reference operation of the technological process.

1. Introduction
Flow production [1] is a very productive tool in the hands of technologists. This method of organizing production involves the sequential execution of technological operations in the field with special equipment and the cyclical or continuous movement of the product or processed raw materials. Its advantage is the narrow specialization of workplaces, the continuity of the production process and, consequently, a high equipment load factor [2]. However, for the successful implementation of these potential properties, a clear consistency and simultaneity of performing various operations with the kanban control method (just in time) is necessary [3]. It is clear that multidimensional monitoring of the duration of each of the operations of the technological process is required here [4-7]. Information obtained as a result of monitoring allows organizing management at the proper level [8]. Since there are many operations, and the loss of time on one operation can be compensated for subsequent ones, control of the duration of each operation is not very informative. In addition, the total sum of the durations of all operations is important because it determines the performance of in-line production. In this case, it becomes relevant to consider the state of the technological process in a multidimensional space, the coordinates of the depicting point in which are the duration of each of the operations at a given time.
2. Theory

The ideas of multidimensional space were expressed in the 18th century by I. Kant and J. D’Alamber, and multidimensional geometry was constructed by A. Cayley, G. Grassmann and L. Schleffli in the past century [9]. Obviously, in stable conditions of the technological process, the duration of each operation on average is observed. It is also important the ratio of the duration of operations with each other. If the durations of all operations are coordinates in the multidimensional space $x_i$, then the locus of points having the same relationship between the coordinates will be a ray coming from the origin, described by the equation

$$x_i = tx_{Ai}$$

(1)

where $x_{Ai}$ are the components of the radius of the vector defining this ray, $t$ is an arbitrary parameter allowing the point representing this process to run along the ray. Let's call it the ray of norms.

As noted in the introduction, the sum of all coordinates, which determines the performance, is also important; the deviation of this sum must also be monitored. The locus of points with the same sum of coordinates in a multidimensional space is the hyperplane, described by the equation

$$\sum_{i=1}^{n} x_i + D = 0$$

(2)

where $n$ is the number of operations in the process.

A distinctive feature of this formula is the unit coefficients at all coordinates. For two coordinates, this property has a straight line running at an angle of 45 degrees to the axes of coordinates. On such a line for each point, an increase in one coordinate leads to an equal decrease in the other, so that the sum of the coordinates will be saved.

Similar reasoning in three-dimensional space leads to a plane inclined at equal angles to all coordinate planes; the hyperplane, which can be called the hyperplane of equal contributions, should have the same property.

Therefore, in order to preserve the properties of an equal contribution in formula (2), the coordinates must be equal. However, the actual duration of the course of operations can vary greatly from each other. To overcome this problem, we use scaling factors. In Figure 1, the operations of the streaming process in the amount of 10 are arranged in ascending order of their duration and are marked on the horizontal axis with their number, and on the vertical axis the corresponding histograms in arbitrary units reflect their duration.

\[\text{Fig. 1. Determination of scaling factors.}\]

Let us take the average level of these histograms as the reference level. As follows from the figure, operations 1 to 5 have scale factors greater than one, and from 7 to 10 less than one.

Turning to the new coordinates, we will be able to compare processes with the same total duration, since they lie in the same plane. When the productivity changes, the hyperplane moves along the beam in one direction or another: it decreases as the point representing the technological process moves
along the beam as it moves away from the origin of coordinates and increases as the point represents the opposite direction.

3. Model

The beam of norms can be constructed using the statistics of the selected technological process. To determine the position of the vector defining the beam by formula (1) taking into account the scale factors, we use the method described in [10]. This method differs from the usual least squares method only in that the distance between the points is taken in the plane of equal contributions.

\[ \sum_{j=1}^{n} x_{ij} (\sum_{k \neq i, k=1}^{n} x_{Ak})^2 + x_{Ai} \sum_{k \neq i, k=1}^{n} x_{Ak} (\sum_{j=1}^{m} x_{ij} - \sum_{j=1}^{m} \sum_{i=1}^{n} x_{ij}) = 0 \quad i = 1, \ldots, n \]  

(3)

Here \( x_{ij} \) is the \( i \)-th coordinate of the \( j \)-th realization of the technological process, the total realizations of \( m \).

However, in practice, the depicting point describing this technological process will deviate in the plane of equal contributions from the point of intersection of this plane with the ray of norms. This is due to local circumstances arising from the performance of operations.

The difference between a real technological process and a normal one (deviation from the norm beam) can be estimated by two parameters determined in the plane of equal contributions: the distance \( \rho \) of the imaging point from the point of intersection of the norm beam and the plane of equal contributions and the angle of rotation of the beam \( \varphi \) on the imaging point in the plane of equal contributions.

To determine the distance of the imaging point \( B \), you must first build a plane with the same sum of coordinates (performance of the streaming process). To do this, we substitute its coordinates into equation (2) and find the parameter \( D \). Finally, the equation of this plane

\[ \sum_{i=1}^{n} x_i - \sum_{i=1}^{n} x_{Bi} = 0 \]  

(4)

Now it is necessary to find the point \( C \) of the intersection of the norm ray with the plane thus defined, for which we substitute the coordinates (1) into equation (4) and determine the desired point \( C \) through the parameter \( t \)

\[ t_C = \frac{\sum_{i=1}^{n} x_{Bi}}{\sum_{i=1}^{n} x_{Ai}} \]  

(5)

As a result, the distance is estimated by the following formula

\[ \rho = \frac{\sum_{i=1}^{n} (x_{Bi} - \frac{\sum_{i=1}^{n} x_{Bi}}{\sum_{i=1}^{n} x_{Ai}} x_{Ai})^2}{\sqrt{\sum_{i=1}^{n} (x_{Bi} - \frac{\sum_{i=1}^{n} x_{Bi}}{\sum_{i=1}^{n} x_{Ai}} x_{Ai})^2}} \]  

(6)

The angle of rotation of the beam on the imaging point in the plane of equal contributions must be counted from some line. Let us take in this quality the line of intersection of the constant plane along the support (first) operation, which is the most stable in the technological process in terms of execution time with the plane of equal contributions. The equation of this line is as follows

\[ \begin{cases} \sum_{i=1}^{n} x_i - \sum_{i=1}^{n} x_{Bi} = 0 \\ x_1 = const = x_{C1} \end{cases} \]  

(7)

For simplicity, we translate the definition of this line as a line passing through two points \( C \) and \( D \), where the last point is the point of intersection of the line given by system (7) and the coordinate plane formed by the first and second coordinate axes. The second coordinate of point \( D \) is found by substituting the second equation (7) into the first

\[ x_{C1} + x_{D2} + 0 + \cdots + 0 - \sum_{i=1}^{n} x_{Bi} = 0 \]  

(8)

From here

\[ x_{D2} = \sum_{i=1}^{n} x_{Bi} - x_{C1} \]  

(9)

The angle between the straight lines \( CB \) and \( CD \) is determined by the scalar product

\[ \cos \varphi = \frac{|CD|}{|CB||CD|} \]  

(10)

From here

\[ \varphi = \arccos \left( \frac{\sum_{i=1}^{n} x_{Bi} - x_{C1} - x_{C2} \cdot \sum_{i=1}^{n} x_{Bi} - x_{C2} + \sum_{i=3}^{m} x_{C1}(x_{Bi} - x_{C1})}{\sqrt{\sum_{i=1}^{n} x_{Bi} - x_{C1} - x_{C2}}^2 + \sum_{i=3}^{m} x_{C1}^2 \cdot \sum_{i=1}^{n} (x_{Bi} - x_{C1})^2} \right) \]  

(11)
Using this technique, information of multidimensional space is integrated in only three indicators: performance, remoteness of the imaging point and the angle of rotation of the beam.

4. Data and modeling results
To test the effectiveness of the proposed technique, a beam of norms was constructed based on the noise of one implementation of a streaming technological process, including ten operations presented in the histograms of Figure 1. For this, the histograms were blurred with variance 2 and shifted by two units as well. The duration of operations is reduced to conventional units and are presented in the table.

| Product number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----------------|---|---|---|---|---|---|---|---|---|----|
| The duration of the operation, convent.units | 1 | 3 | 4 | 5 | 8 | 10 | 11 | 15 | 17 | 21 |

The results of the calculations are presented in Figure 2.

5. Discussion
The results are presented in a cylindrical coordinate system; on a horizontal plane, the distance $\rho$ and the rotation angle $\phi$ are deposited. The vertical axis lays the current performance of the streaming process. A technologically acceptable niche is highlighted by a cylinder, therefore approaching the boundaries of this cylinder and, moreover, going beyond them should be taken by the marketing service as a guide to action. Moving the cylinder vertically upwards means decreasing productivity, going beyond the lateral formers means skewing the duration of operations in production in one direction or another. The results obtained quite clearly show the effectiveness of the developed technique, which increases with increasing number of observed parameters.

6. Conclusions
Thus, multidimensional monitoring of a streaming process using three indicators allows monitoring not only the absolute values of the indicators, but also the relationship between them, increasing the speed of the control system in response to abnormal deviations, and finally, increasing the visibility of the monitoring information.
References

[1] Organization and planning of engineering production M.: Engineering, 1974 591 p
[2] Pishchukhin A 2017 Metasystem approach to increase the load factor of the FMS MATEC WebMeeting Conferences & ICMTMTE 2017 P. 04003
[3] Magee D How Toyota Became №1 - Leadership Lessons from the World's Greatest Car Company, Portfolio Hardcover (November 2007) ISBN 978-1-59184-179-1
[4] Pishchukhin A, Akhmedyanova G 2018 Algorithms for synthesizing man-age solutions based on OLAP-technologies Journal of Physics: Conference Series Ser. "International Conference Information Technologies in Business and Industry 2018 - Enterprise Information Systems" P. 042001.
[5] Bulaeva N, Musalov S 2017 A “GEM GIS” data module for synchronization of data. Monitoring Science and Technology 1 p 38–45
[6] Tarakanov D 2010 Method of modification of the vector criterion in the decision support system for extinguishing a large fire Technosphere Safety Technologies 2 http://ipb.mos.ru /ttb.
[7] Tarakanov D 2017 Multi-criteria model of the management of fire and rescue units Technosphere Safety Technologies 4(74) p 148-154
[8] Ahmedyanova G 2017 Simulator as a tool of training to modern equipment management MATEC Web of Conferences Cep. "International Conference on Modern Trends in Manufacturing Technologies and Equipment, ICMTMTE 2017" S 06019
[9] Yushkevich A 1972 The history of mathematics (volume 3). Mathematics of the XVIII century (Moscow: Nauka) 496 p
[10] Akimov S, Vedeneev P, Kiyeva E, Laryushina I, Notova S, Pishchukhin A 2017 A multidimensional approach to assessing the organism Journal of Physics: Conference Series 913 1 P. 012002