Algorithms for synthesizing management solutions based on OLAP-technologies

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Abstract. OLAP technologies are a convenient means of analyzing large amounts of information. An attempt was made in their work to improve the synthesis of optimal management decisions. The developed algorithms allow forecasting the needs and accepted management decisions on the main types of the enterprise resources. Their advantage is the efficiency, based on the simplicity of quadratic functions and differential equations of only the first order. At the same time, the optimal redistribution of resources between different types of products from the assortment of the enterprise is carried out, and the optimal allocation of allocated resources in time. The proposed solutions can be placed on additional specially entered coordinates of the hypercube representing the data warehouse.

1. Introduction

OLAP-technologies are a convenient tool for analyzing large amounts of information. Convenience and speed of analysis are due to the structuring of data based on the hypercube. And the analysis itself is carried out naturally with the aim of synthesizing managerial decisions. However, algorithms for synthesizing such solutions are often absent in OLAP-technologies. At the same time it is logical, having large volumes of actual data, to synthesize simultaneously alternative managerial decisions and offer them for final choice to the decision-maker.

2. Theory

It is impossible to accept any managerial decision without having the information necessary for this, usually quantitative. This requires the creation of data warehouses. They are assigned to the process of collecting, screening and preliminary processing of data in order to provide the resulting information to users for statistical analysis, and often creating analytical reports [1]. Ralph Kimball, one of the authors of the concept of data warehousing, described the data warehouse as "a place where people can access their data" [2,3,4].

The concept of OLAP was described in 1993 by Edgar Codd, a well-known database researcher and author of the relational data model [5]. In 1995, based on the requirements set by Codd, the so-called Fast Analysis of Shared Multidimensional Information (FASMI) was formulated. The relevance of using OLAP systems is to provide the ability to work with data in terms of the subject area without the knowledge of the information storage architecture [6]. The main goal of the development of OLAP technologies is to provide the user with structured information tools to explain current data and build forecasts [7].

In various OLAP products, there are two main options for organizing data [8] in multidimensional
cubes: a hypercubic model and a polycubic model. Such representation would be useful in model problems [9]. In this case, the functions of sampling, processing and presentation of data can be assigned to a special OLAP machine [10].

Hypercube is initially multidimensional and its dimension is not limited in any way. For example, by postponing the volumes of products produced by its coordinates, it is possible to obtain assortment space [11]. The cube as a matter of fact represents a "photos" set of system’s indicators of the enterprise condition consistently in time. This allows one to apply the step-by-step method of dynamic programming Bellman to optimize the redistribution of enterprise resources, and then, the proposed solutions can be placed on additional specially entered hypercube coordinates.

To formulate the problem of optimal redistribution of resources, it is necessary to know the efficiency functions of their investments in the production of a particular product from the assortment. In the first approximation, one can confine oneselfs to a quadratic function:

\[ \psi_i = \tau U_i - v U_i^2 \]  
(1)

Here \( U_i \) is the value of the resource directed to the production of the i-th product, of \( \tau, v \) are the constant coefficients chosen for the approximation.

Let us compose the Bellman function [12]:

\[ \varphi(i, X_i) = \max_{U_i \geq 0} \{ \varphi(i + 1, X_i + U_i) + \psi_i(i, U_i) + M[X_i(N) - Z]^2 \} \]

(2)

Where \( N \) is the total number of products, \( i \) is the serial number of the product type, \( X_i \) is the cumulative variables, \( M \) is the large number in the penalty function, and \( Z \) is the total resource of the enterprise:

\[ U_i = \text{arg max}_{U_i \geq 0} \{ \varphi(i + 1, X_i + U_i) + \psi_i(i, U_i) + M[X_i(N) - Z]^2 \} \]

(3)

After solving the problem that determines the allocated resources, it is logical to develop an algorithm for supplying them to control objects, for example, determined by the Euler-Lagrange method.

Functionals of optimal inventory management are set as follows:

\[ \int_{t_0}^{t_1} (Q_i^2 + \alpha u_i^2) dt \to \min \quad i = 1, \ldots, I, \]

(4)

Here the method of analytic construction of the regulators of Professor A.M. Letov, in which the quadratic dependences of control actions and performance indicators are introduced into the functional by means of a coefficient equalizing the dimension \( \alpha \). Here, also \( Q_i \) - stocks of the i-th resource in the warehouse, \( u_i \) - the value of the order of this resource type, \( t_{n}, t_{k} \) - the time of the beginning and the end of the control.

The results of solving this problem can also be represented on additional specially introduced hypercube coordinates.

### 3. Model and Method

Most often, production tasks are associated with the replenishment of stocks of various resources. This process can be described by a simple equation:

\[ \frac{dQ_i}{dt} = u_i - R_i, \]

(5)

where \( R_i \) is the expense of the i-th resource.

Then the Lagrangian can be written in the form:

\[ L = Q_i^2 + \alpha u_i^2 + \lambda_i (\frac{dQ_i}{dt} + R_i - u_i), \]

(6)

where \( \lambda_i \) is the i-th Lagrange multiplier.

To find the optimal control, it is necessary to compose the Euler equations:

\[ \frac{dU_i}{dQ_i} - \frac{d}{dt} \left( \frac{dU_i}{dQ_i} \right) = 0; \frac{dU_i}{du_i} = 0; \frac{dU_i}{d\lambda_i} = 0. \]

(7)

Substituting the Lagrangian, let us obtain the system of equations:
Transforming the first two equations, let us obtain:

\[
\begin{align*}
2Q_i - \frac{d\lambda_i}{dt} &= 0 \\
2\alpha u_i - \lambda_i &= 0 \\
\frac{dQ_i}{dt} + R_i - u_i &= 0.
\end{align*}
\]  

(8)

Substituting the expression of the variables from the first two equations in the third equation (8), let us obtain:

\[
\alpha \frac{d^2u_i}{dt^2} - u_i = -R_i.
\]  

(10)

The solution of the corresponding homogeneous equation is expressed in terms of the hyperbolic functions:

\[
u_{0i}(t) = C_1 \cosh \frac{t}{\alpha} + C_2 \sinh \frac{t}{\alpha}.
\]  

(11)

A particular solution must be sought in the form of the right-hand side of equation (10):

\[u_i = AR_i.
\]  

(12)

Substituting this expression into equation (10), we obtain the equation:

\[
\frac{d^2R_i}{dt^2} + \frac{1-A}{\alpha} R_i = -R_i.
\]  

(13)

The solution of this equation, depending on the sign of the fraction [13]:

\[
R_i = u_i = \begin{cases} 
C_3 \cosh \frac{\alpha^{-1} + \beta}{2} t + C_4 \sinh \frac{\alpha^{-1} - \beta}{2} t & \text{when } (1-A)^2 - 4 > 0 \\
\exp \frac{\alpha^{-1} t}{2} (C_3 + C_4 t) & \text{when } (1-A)^2 - 4 = 0 \\
C_3 \cosh \frac{\beta t}{2} + C_4 \sinh \frac{\beta t}{2} & \text{when } (1-A)^2 - 4 < 0
\end{cases}
\]  

(14)

Here \( \beta^2 = \frac{(1-A)^2}{\alpha^2} - 4 \)

Now the algorithm of actions is clear – there is a need to analyze the data: if function \( R_i \) is approximated by a harmonic, then the third solution fits us, if the monotone exponent, then the first one is suitable, in all other cases let us choose the second solution and so all the constants \( (A, C_3, C_4) \) approximated function \( R_i \).

Substituting the solution obtained into the general solution and into the first equation in system (9), let us obtain:

\[
\begin{align*}
\nu_i &= C_1 \cosh \frac{t}{\alpha} + C_2 \sinh \frac{t}{\alpha} + AR_i \\
Q_i &= C_1 \sqrt{\alpha} \sinh \frac{t}{\alpha} + C_2 \sqrt{\alpha} \cosh \frac{t}{\alpha} + A \frac{dR_i}{dt}.
\end{align*}
\]  

(15)

(16)

Using the initial values of the resource reserve:

\[
\nu_{0i}, \text{ when } t = 0,
\]  

(17)

and the condition of limited resources \( (U_i, \text{ let us take from equation (3)), one obtains:} \)

\[
\begin{align*}

Q_{ni} = C_2 = \sqrt{\frac{1}{\alpha}} (Q_{ni} - A \frac{dR_i}{dt}) \\
\int_{t_n}^{t_e} (C_1 \cosh \frac{t}{\alpha} + \sqrt{\frac{1}{\alpha}} (Q_{ni} - A \frac{dR_i}{dt}) \sinh \frac{t}{\alpha} + AR_i) dt = U_i.
\end{align*}
\]  

(18)

4. Data and methods

Data for the test case were taken from the milk processing plant [14]. The products of this enterprise
have been in demand for a long time among residents of Orenburg and the region. Natural ingredients and high quality of production are the distinctive features of all dairy products of the creamery. In addition, this production is distinguished by a large assortment - up to 10 positions and short shelf life of products from 3 to 10 days. This circumstance exacerbates the requirements for the speed and accuracy of planning production volumes.

5. The results and discussion
The developed algorithm includes the optimal distribution of the enterprise's production resources, primarily financial by product, approximating the resource consumption for the previous period and forecasting this expenditure for the next period in accordance with the derived formulas (15,16). In Figure 1, a sales histogram is shown, and in Figure 2 - a histogram of the projected investments of control resources, calculated on the basis of the average representation of the expense function in (15).

![Figure 1](image1)

**Figure 1.** The histogram of sales of the selected product for the week

![Figure 2](image2)

**Figure 2.** The histogram of the optimal predictive investment of control resources for the next week

The type of the predictive function is easily chosen by minimizing the error in the approximation of real data.

6. Conclusion
Thus, the developed algorithms for synthesizing management decisions based on OLAP-technologies are a convenient tool of the system analyst, which allows forecasting the needs and accepted
management decisions on the main types of the enterprise resources. Their advantage is the efficiency, based on the simplicity of quadratic functions and differential equations of only the first order.

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