Modeling and optimization of software components for control of industrial enterprises

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Abstract. In this paper, we consider the approach associated with managing large industrial companies using different types of software. In solving this problem, we relied on computer technology, modeling and optimization techniques. An algorithm is proposed for modeling and optimizing software components during the management of industrial enterprises. A diagram illustrates the operation of this algorithm. The paper gives some results showing an increase in the efficiency of an industrial organization based on the use of the proposed algorithm.

1. Introduction
In order to ensure the management of large industrial companies, including those that are geographically distributed, it is necessary to develop and apply program-situational structures. Based on them, a grouping of a variety of situations occurs. They can be combined into sets. Situations correspond to various kinds of conditions within organizations [1, 2]. In addition, it is necessary for them to provide for an appropriate number of program-targeted activities. They will correspond to different areas of activity of an industrial company.

The aim of this work is to develop an algorithm on the basis of which modeling and optimization of software components in industrial organizations is carried out to increase their efficiency [3, 4].

2. Model of software components in a large industrial organization
It is necessary to provide support for the processes of modeling software-situational structures. At the same time, it is important that elements related to set of situations are formed $r = 1, R$. Here we used the following notation: $R$ - corresponds to the total number of situations that may arise within the analyzed company, as well as to the many types of software implemented $v = 1, V$. In this case, we use the notation $V$, corresponding to the total number of software programs. During the simulation, such software elements are considered in the form of control actions. After we have designated the corresponding sets, it is required to evaluate how much they correspond to each other by the elements $r$ and $v$. We need to solve management problems. Therefore, in sets, the elements must be ordered. The streamlining process is based on the fact that the elements will take into account the significance
when management decisions are made. At the same time, one has to rely on the performance indicators of an industrial company [5].

We indicate how the ordering process can be carried out by the elements that will be included in the sets $R$ and $V$. It is necessary that the method of expert assessments be used. Expert assessments should be calculated in several ways. The first is related to how quality control occurs during the implementation of production processes. The second is related to the degree of environmental friendliness of production processes [6]. The third is based on consideration of how efficiently different types of resources will be used. To solve such problems it is necessary to apply the a priori ranking method [7].

Next, we consider the features of how this method will be used in the problem under consideration. It is required to obtain estimates for the ranks $Q_r$ and $Q_v$, which are obtained by analyzing the sets $R$ and $V$. In what follows, a probability representation is used for such estimates:

$$
p_v = Q_v / \sum_{v=1}^{V} Q_v, \quad v = 1, V, \quad \sum_{v=1}^{V} p_v = 1,
$$

$$
p_r = Q_r / \sum_{r=1}^{R} Q_r, \quad r = 1, R, \quad \sum_{r=1}^{R} p_r = 1. \quad (1)
$$

In these expressions, we use the following notation: $p_r$ - is considered as a probabilistic assessment, demonstrating the significance of the component $r$; $p_v$ - is considered as a probabilistic assessment, demonstrating the significance of component $v$.

In real situations, various combinations of the $r$ and $v$ components can be found. It depends on the type of tasks being solved at the enterprise, their complexity. Then the components $r$ and $v$ will be characterized by varying degrees of heterogeneity. That is, when effective management decisions are formed, they will have a different degree of significance. It can be estimated based on a consideration of the values of entropy [8] have conflicting interests in the use of resource provision production system for the $n$-th focus (1):

$$
H(R) = - \sum_{r=1}^{R} p_r \cdot \lg p_r, \quad H(V) = - \sum_{v=1}^{V} p_v \cdot \lg p_v. \quad (2)
$$

For entropy values, there are certain properties that relate to its value. If the probabilities $p_r$, $p_v$ will relate to a uniform distribution, then the magnitude of the entropy will increase. The more the distribution will have greater unevenness, the less important will be for entropy.

For maximum entropy values, the following formulas can be used

$$
H(R) = \lg R, \quad H(V) = \lg V. \quad (3)
$$

Based on the analysis of such quantities, a quantitative description can be made of what changes will be in the characteristics of an industrial enterprise, and what may be the possibility of its development.

It is necessary to analyze all possible distributions that characterize the components during the analysis [9]. Otherwise, there are risks that for certain combinations of components $r$ and $v$ not all possible options associated with their combination will be taken into account. This may result in management being completely ineffective. The control system should work in the same way when we observe different combinations of components. In this regard, the level of heterogeneity will be determined in a rational way by using the coefficient of non-uniformity $\delta$ ($0.4 \leq \delta \leq 0.7$). The formula shows how the assessment of the level of heterogeneity will be carried out:

$$
H^{rac}(R) = \delta \cdot \lg R, \quad H^{rac}(V) = \delta \cdot \lg V. \quad (4)
$$
Various situations during production processes are described on the basis that the appropriate elements of information and telecommunication equipment are used. These elements have different effects on how the components will change in many situations [10, 11].

Let us consider the influence of the element \( v \) on the components that will describe the set \( R_{r} \),

\[
R_{r} = 1, R
\]

The effect may be different. It is proposed to break it into ranges that correspond to expert estimates \( Q_{rv} \) given in the expression

\[
Q_{rv} = \begin{cases} 
  \text{strong (10 scores)} \\
  \text{significantly (8 scores)} \\
  \text{some (6 scores)} \\
  \text{little (4 scores)} \\
  \text{few (2 scores)} 
\end{cases} 
\]  

(5)

The process of calculating conditional probabilities is based on the values of expert estimates

\[
P( r / v ) = Q_{rv} / \sum_{v=1}^{V} Q_{rv} .
\]

(6)

In order for management in an industrial enterprise to be effective, appropriate decisions must be made. Conditional entropy can be considered as some characteristic during decision making. The expressions illustrate how conditional entropy is calculated:

\[
H_{v}( R ) = \sum_{r=1}^{R} p_{r} H_{v}( r ) , \quad H_{v}( r ) = - \sum_{v=1}^{V} p( r / v ) \cdot \log p( r / v ) .
\]

(7)

Quality control, as well as the degree of effectiveness of the functioning of all divisions of an industrial enterprise should be determined jointly. This illustrates an expression describing a program structure.

\[
H( R,V ) = H( V ) + H_{v}( R ) .
\]

(8)

As noted above, the priorities will be different. In this regard, it is important to assess the adequacy of the priority model. This is determined by the selected software structure option

\[
H( R,V ) = H^{ rac}( R,V )
\]

(9)

The optimization process according to the program structure occurs using the appropriate model. It describes the priorities associated with the components \( r \) and \( v \), as well as the interactions between them. Therefore, alternative variables are required:

\[
x_{v} = \begin{cases} 
  1, \text{if } v \text{-th influence, will be in the program} \\
  0, \text{in other cases} 
\end{cases} \text{of functioning in industrial enterprise , } v = 1, V .
\]

(10)

Each type of software requires corresponding financial costs. It should be borne in mind that since resources will be limited, it is therefore necessary to minimize the number of elements \( v \). It should be borne in mind that the support for each situation \( r \) from the side of activities that will be in the target program components. Support may not be complete, but at least partially. These restrictions must be considered. The rules of most apply. For this, the discrete value \( C_{rv} \) is considered, which will be characterized by three levels. Then the probabilistic estimates \( p( r / v ) \) will correlate with sets of values
The following notation is introduced: $z_v$ are the predicted costs that will be associated with the fact that the $v$-th type of software is being implemented.

### 3. Simulation algorithm

A simulation was carried out in which the developed optimization model was used. During its implementation, several options for software products are considered. Their number is between 5 and 10. It is necessary to apply different costs in order to realize them. At the same time, a different level will be ensured at which the efficiency of production processes will increase. For the experiment to be implemented, the following operation must be carried out. Alternative variables $x_v$ will be replaced with random discrete variables $\tilde{x}_v$. Moreover, for them, the distribution will be described by the following parameters:

\[
p(\tilde{x}_v = 1) = p(x_v), \quad p(\tilde{x}_v = 0) = g_{xv} = 1 - p_{xv}.
\]  

A sequence of pseudorandom numbers $v = 1, V$ was generated. Their feature is that they will have a uniform distribution. This distribution corresponds to the interval $(0,1)$. Those variables that will vary must be set accordingly. The pattern is described on the basis of the following expression:

\[
\tilde{x}_v = \begin{cases} 
1, & \text{if } v \leq p_{xv} \\
0, & \text{in other cases.}
\end{cases}
\]  

We consider the description of the simulation experiment when subject to the following conditions. 1. Discusses a probabilistic approach. 2. In optimization models will be considered limited.

Random processes are analyzed in the form of random walks. It is described on the basis of the corresponding Markov chain.

You must correctly describe the condition of this circuit. They are associated with different combinations that will meet the alternative variable $x_v$, $v = 1, V$. If we choose promising combinations of software components, then they can relate to absorbing States. During the simulation of any cycle provides opportunities to receive promising option variants. This can be explained by the peculiarity of the Markov chain.

The probability of a transition to absorb as will be implemented over a certain number of steps will be equal to one.

The transition will be from an arbitrary initial state [13]. A Markov chain is characterized by the property of irreducibility.

After the conducted simulation, we will have a set of promising options.

These options are discussed from the point of view of expert analysis. The analysis is performed by management of an industrial enterprise.

Then the formation of the totality of optimized software modules that will meet the designated purposes of functioning and development of industrial enterprises [14, 15].
In figure 1 shows a diagram associated with the simulation and optimization software. It is based on that used computer control technology.

![Diagram illustrating software modeling and optimization.](image)

**Figure 1.** Diagram illustrating software modeling and optimization.

### 4. Results
The solution to the problem of optimizing software within an industrial enterprise was carried out. In total, 34 organizations were allocated in this organization. For the implementation of production functions, 8 types of software components were used. A total of 374 workstations were considered.

In the initial period of time, the efficiency of an industrial company was adopted as 1, that is 100%.
Figure 2 shows the change in the efficiency of the enterprise without use (curve 1) and using the developed algorithm (curve 2). During the period under review, the number of production tasks that were required to solve at the analyzed production enterprise increased from 73 to 116.

5. Conclusion
The decision-making process during the control of industrial enterprises is influenced by the using of software components. This is due to the fact that at present a large number of production and technological processes are being automated. The model of software components in a large industrial organization is considered. It is proposed to break software components into ranges that correspond to expert estimates. The simulation algorithm is developed. The results with use of proposed algorithm and model are obtained. They demonstrated that through the optimization and modeling of software components in the organization, its efficiency can be significantly increased.

References
[1] Orlova D E 2018 Stability of solutions in ensuring the functioning of organizational and technical systems Modeling Optimization and Information Technologies 6(1) 325-36
[2] Sorokin S O 2018 Optimization modeling of the functioning of the system of homogeneous objects in a multidimensional digital environment Modeling optimization and information technologies 6(3) 153-64
[3] Pekka Neittraanmiki, Sergey Repin and Tero Tuovinen Eds. 2016 Mathematical Modeling and Optimization of Complex Structures; Series: Computational Methods in Applied Sciences (Springer International Publishing AG, Switzerland)
[4] Rios L M and Sahinidis N V 2013 Derivative-free optimization: a review of algorithms and comparison of software implementations Journal of Global Optimization 54 1247-93
[5] Hugo Morais, Péter Kádár, Pedro Faria, Zita A Vale and Khodr H M 2010 Optimal Scheduling of a Renewable Micro-Grid in an Isolated Load Area Using Mixed-Integer Linear Programming Elsevier Editorial System(tm) for Renewable Energy Magazine 35(1) 151-6
[6] Odu G O and Charles-Owaba O E 2013 Review of Multi-criteria Optimization Methods Theory and Applications 3 1-14
[7] Talluri S, Kim M K and Schoenherr T 2013 The relationship between operating efficiency and service quality: are they compatible? Int. J Prod Res 51 548-2567
[8] Shah A and Ghahramani Z 2015 Parallel predictive entropy search for batch global optimization of expensive objective functions Advances in Neural Information Processing Systems 3330-38
[9] Yao Y and Chen J 2010 Global optimization of a central air-conditioning system using decomposition-coordination method *Energy and Buildings* 5 570-83

[10] Lvovich I, Preobrazhenskiy A, Preobrazhenskiy Y, Lvovich Y and Choporov O 2019 Managing developing internet of things systems based on models and algorithms of multi-alternative aggregation *Int. Seminar on Electron Devices Design and Production SED-2019 - Proceedings* p 879-8413

[11] Lvovich I Ya, Lvovich Ya E, Preobrazhenskiy A P, Preobrazhenskiy Yu P and Choporov O N 2019 Modelling of information systems with increased efficiency with application of optimization-expert evaluation *Journal of Physics: Conf. Ser. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations; Polytechnical Institute of Siberian Federal University Bristol United Kingdom* 33079

[12] Groefsema H and van Beest N R T P 2015 Design-time compliance of service compositions in dynamic service environments *Int. Conf. on Service Oriented Computing & Applications* 108-15

[13] Weber I, Xu X, Riveret R, Governatori G, Ponomarev A and Mendling J 2016 Untrusted Business Process Monitoring and Execution Using Blockchain 329-47

[14] Lee S, Liao Y, Seo M H and Shin Y 2018 Oracle estimation of a change point in high dimensional quantile regression *Journal of the American Statistical Association* 113:523 1184-94

[15] Riza L S, Bergmeir C, Herrera F and Benítez J 2015 Fuzzy Rule-Based Systems for Classification and Regression in R *Journal of statistical software* 65(6) 1-30