ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНІ ТА ОБЧИСЛЮВАЛЬНІ СИСТЕМИ І КОМПЛЕКСИ В ТЕХНОЛОГІЧНИХ ПРОЦЕСАХ

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IMPROVEMENT OF COORDINATION OF DISTRIBUTED INDUSTRIAL OBJECTS BY SEARCH METHODS

The paper presents the benefits of the sampling techniques when working with functions that are defined within a multidimensional search space. In addition, it is presented a new heuristic approach of random search, which has the potential to find optimal solutions for different types of coordination problems.
Key words: random search, scheduling, resource allocation, coordination of locally distributed objects.

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ПОВЫШЕНИЕ КООРДИНАЦИИ РАСПРЕДЕЛЕННЫХ ПРОМЫШЛЕННЫХ ОБЪЕКТОВ ПОИСКОВЫМИ МЕТОДАМИ

В этой работе приведены преимущества методов отбора проб при работе с функциями, которые определены в многомерном пространстве поиска. Кроме того, представлен новый эвристический подход случайного поиска, который имеет потенциал нахождении оптимального решения для различных типов задач координации.
Ключевые слова: случайный поиск, планирования, распределения ресурсов, координации локальных распределенных объектов.

Objective.

The aim of the present article is to improve the coordination of operations of local processing lines.

Introduction

The spatial distribution of technological objects introduces a challenge in the coordination process. The isolated work of the elements of a complex system often leads to numerous problems and generates a high degree of uncertainty in management decisions. Thus, to achieve an overall objective is necessary to coordinate the interactions [1, 2].

The process of preparation and packaging of milk requires a task automation, which should provide the following operations: receiving, separation, homogenization, normalization, packaging and packing. Each operation is a time-consuming process that requires continuous monitoring. Let's study the coordination in a specific case. A dairy plant manufactures three products, which are stored in a temporal area. For the transport of the products, there is available one mechanism. The presence of only one mechanism makes it very difficult the parallel operation of all the lines and, therefore, it leads to increase of downtime and loss of profits. A diagram of the production management system is shown in Fig. 1

Mathematical model of the system

A mathematical model of the process system connects the parameters of the system. This model includes the equations that reflect the dependence of input and output variables, taking into account the physical and technical constraints. Figure 2 shows the Gantt chart of the production lines and the unload mechanism. From this diagram, it can be deduced that the coordination of the work of the parallel lines is necessary to satisfy the conditions described in the following equations 1 - 3:

$$tl_i + tu_i = T \quad (1)$$

$$\sum_{i=1}^{n} tu_i = T \quad (2)$$

$$\sum_{i=1}^{n} tl_i = (n-1)\sum_{i=1}^{n} tu_i \quad (3)$$

where, n - number of production lines, to_i - the time of beginning of the line i, T - the duration of the load-unload cycle, tl_i - the duration of loading of temporary store B_i - tu_i - the duration of unloading of temporary store B_i.

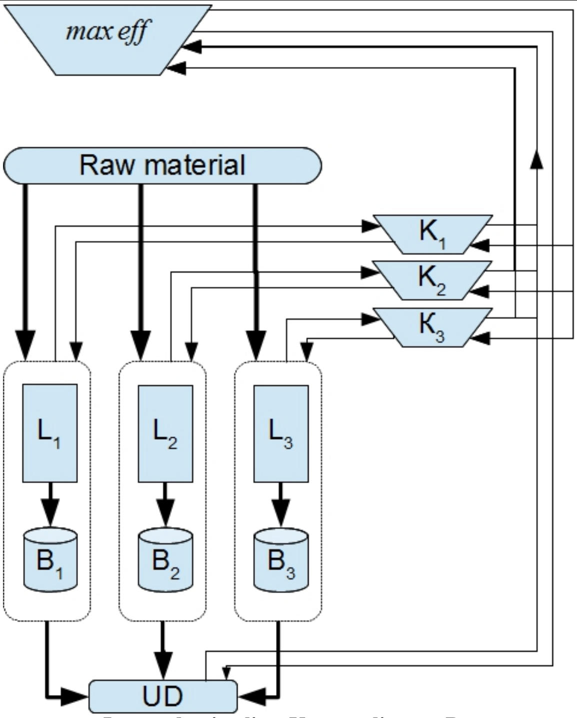

Figure 1: The production management system. L _ production line, K – coordinator, B – temporary store, eff – criterion of effectiveness

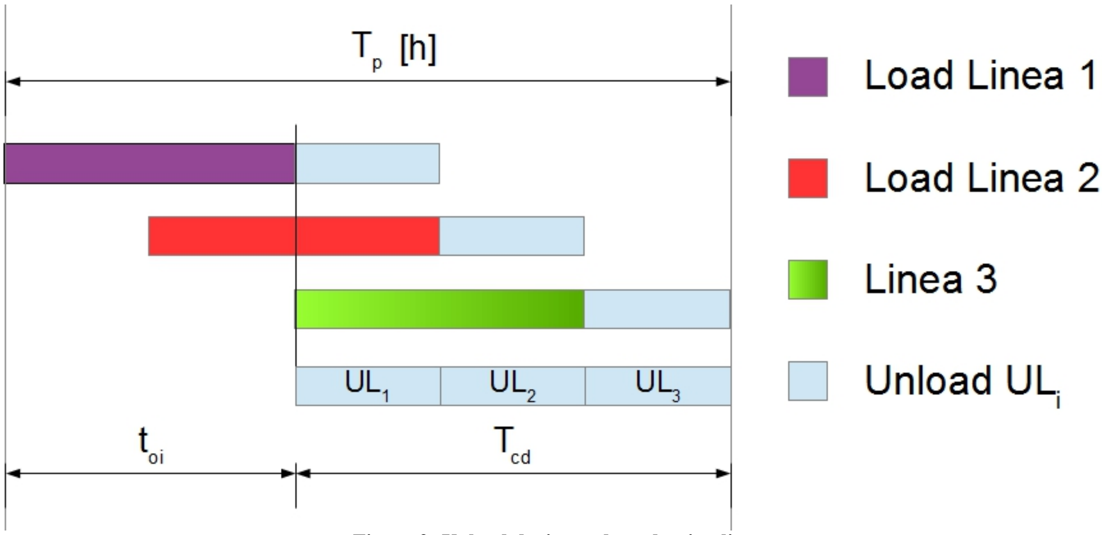

Figure 2: Unload device and production lines

The coordination can be achieved through the variation of the quantities stored in temporary spaces and the variation of the performance of the lines. By the introduction of the coordination variables α_i for temporary store B_i and λ_i for machines performance, equations 1 -3 can be rewritten in the parametric form:

$$T = f(\alpha_i, \lambda_i)$$
$$s.t.$$
$$\sum_{i=1}^{n} \frac{\alpha_i Bmax_i}{\lambda_i p_i} = (n-1) \sum_{i=1}^{n} \frac{\alpha_i Bmax_i}{p_u - \lambda_i p_i} \tag{4}$$

where α_i , λ_i - coordination variables, p_u - performance of the unload device, p_i - the performance of the production lines, and $Bmax_i$ — maximum capacity of the temporary stores.

Thus, the coordination task is reduced to finding a vector $X(\alpha_i, \lambda_i)$, which satisfies the above-mentioned conditions.

Broad classes of problems, including the coordination of activities of production processes, are solved by search methods. These methods aim to find an optimal solution within the "search space," determined by a set of constraints. In many cases, the exploration of the search space requires a lot of computational resources, depending on the nature of the search method used and the particular problem.

Analytical methods, such as gradient methods, do not work well when the search space is multidimensional. Either because they get stuck in local optima or because they do not converge in a reasonable computation time. For this reason, many researchers prefer heuristics techniques for searching global optimal solution.

One of the heuristics methods is the random search, which uses a Monte Carlo technique for selection of possible solutions in the search space Ω, using an uniform distribution [3]. The drawback of the random search method lies in the fact that it takes a long time to converge to a solution for high accuracy.

Improved versions of the basic algorithm of random search consider modifying the mechanism of selecting potential solutions. The existent more effective methods include mechanisms that take advantage of the accumulated knowledge about the criterion of efficiency. For example, many methods for improving the local search use the following relations:

$$X_{k+1} = X_k + \beta d$$

so that (5)

$$f(x_{k+i}) > f(x_k)$$

where, β - scalar, which is a step size of displacement, and d - the direction of the search. The process of choosing the right step size and direction values is an essential difference between the algorithms presented in the literature.

In the work [4], a method for of random search by coordinates is given. Here, the step size is kept constant while the search direction changes when the value of the criterion of the efficiency of the solution X_{K+1} is less than that for the previous one X_K. Thus, the original multi-dimensional problem is replaced by a one-dimensional problem of finding the optimal value of β, which solves:

$$\max_{\beta} f(x_k + \beta d_j) \qquad (6)$$

Thus, the method searches along multiple components of the space, while it is possible to improve the current solution, or some stopping criterion is reached.

Methodology

This section presents the proposed method to improve the coordination of the processing lines. This method consists of the following parts:

a) a technique of sampling and reconstruction of function ***eff***, which meets the criteria of efficiency,

b) a heuristic method of random search in the feasible region, and

c) a heuristic search method to optimize local extrema.

Sampling the function ***eff*** is performed by a normal distribution. For this purpose, a set X_s of m points is generated randomly. The function is reconstructed from the evaluation of *Xs* in eff. In the case of maximization, those points whose function value are above the standard deviation of the set $Ys=eff(X_s)$ are selected as candidates for local extremum.

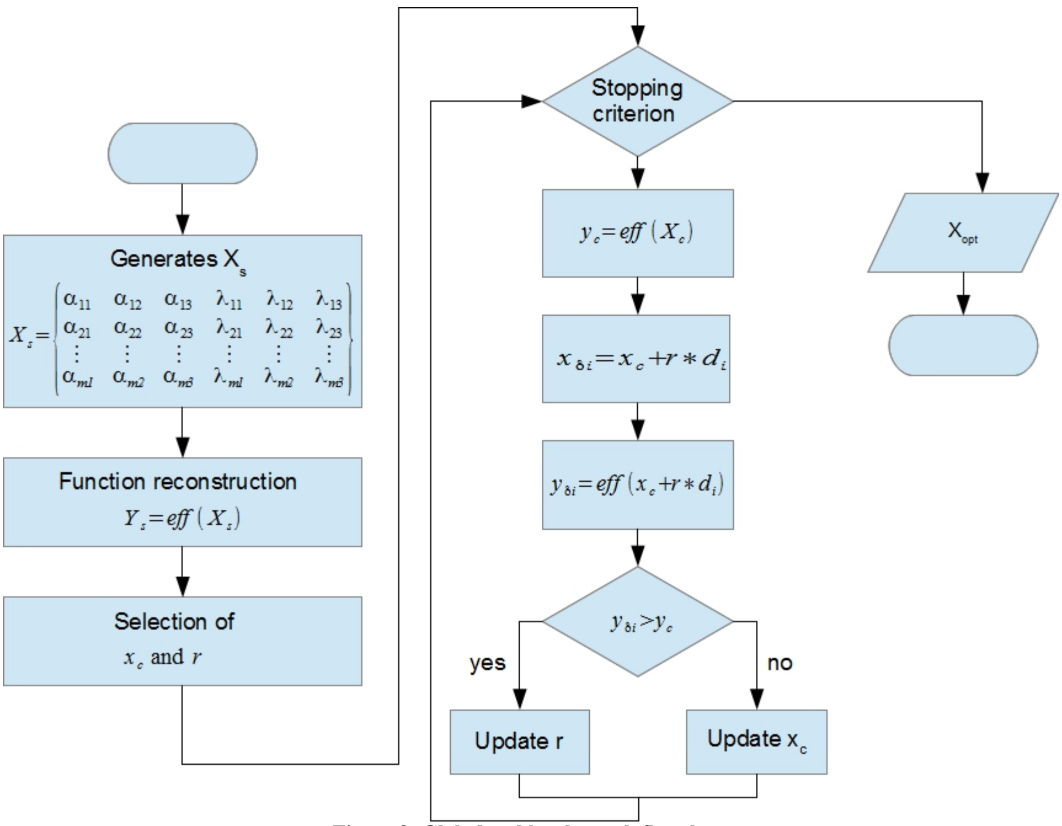

Figure 3: Global and local search flowchart

The input parameters of the local search are the search centers x_c and the search radiuses r. The global search method provides both data sets. The local search consists of an iterative procedure. The points, which are located at a distance r from x_c are evaluated in the function. If for any of these points, the value of the function is not better than for x_c then the search radius is reduced by half. Otherwise, the search center is updated to the point, whose value of ***eff*** is the best. The process iterates until the stopping criterion is not met. The following flowchart illustrates the proposed search method, figure 3.

Results

A set of problems was chosen to test the effectiveness of the proposed method. Each of the problems has a relative complexity and have been commonly used in the literature for the comparison of search techniques. Problem one has two constraints: a non-linear equation and a linear inequality was addressed in [5]. Problem two no restrictions [5]; Then the method was applied to obtain the operating conditions in parallel for a specific case.

Table 1

Test problem	Reported value	Proposed method
$min(x-2)^2+(y-1)^2$ $s.t.$ $x-2y=0$ $0.25x^2+y^2-1\leqslant 0$	$min\ f=1.3930$ $when,$ $x=0.8230$ $y=0.9110$	$min\ f=1.3920$ $when,$ $x=0.8235$ $y=0.9112$
$min(y-x^2)^2+(1-x)^2$	$min\ f=0$ $when,$ $x=1$ $y=1$	$min\ f=0$ $when,$ $x=1$ $y=1$

Data for the coordination of the production lines are summarized in the following table. For the evaluation of the coordination of hundred lines sampling points were used, and alpha parameters were set to 1. It was found that the values of the parameter lambda that allow the parallel work of the production lines are the following: λ_1=0 .8070, λ_2 = 0.7063, and λ_3 = 1.1356. These results were obtained with 250 assessments of the optimization criterion and whose optimum value 0.00082. With a simple random search method, to obtain similar results, requires no less than 500 evaluations of the optimization criteria.

Table 2

n	Performance [T/h]	Temporary store [T]	Unload performance [T/h]
1	7	10	17
2	8	11	
3	5	9	

Conclusions

The proposed solution to the problem of coordination of working process of the enterprise with the use of improved random search technique provides a way to allow parallel operation of the production lines. One advantage of the method is the speed of response. This fact allows to get additional time for the decision-making and thus reduce downtime The developed method of coordination can be adapted to other processes requiring interrelated resource allocation and synchronization.

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