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SOLUTION OF CONTROL TASKS USING BAT ALGORITHM MODIFICATIONS

РОЗВ'ЯЗАННЯ ЗАДАЧ УПРАВЛІННЯ З ВИКОРИСТАННЯМ МОДИФІКАЦІЙ АЛГОРИТМУ КАЖАНІВ

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Abstract. *The work included research of bat algorithms and their modification to solve management tasks at food enterprises. Selection of the bat algorithm on the basis of Levy flight search strategy, which provides formation of alternative plans for order execution, taking into account the proposed mathematical model, the use of which allows to form new plans and to reconfigure existing plans in a short time, was justified.*

Keywords: *planning, production management, order execution, algorithms, bats algorithm.*

Introduction.

Tough competition with internal and external food manufacturers requires managers to respond quickly to consumer demands. It should be noted that the food industry is strategic in any country. In the segment of food products market there is a fierce competition between domestic producers and exporters. Consumers constantly set new requirements to the physical and organoleptic characteristics of products, their range and quality. A modern enterprise cannot use long-term planning of production, because it is necessary to respond quickly to the needs of consumers. The majority of modern information systems are aimed at supporting production management, resource management, automation of planning, accounting, control and analysis of all business operations of the enterprise. Communication between departments is provided through the use of corporate databases and data warehouses.

The main management task is to ensure the production of products in full and assortment to meet the needs of customers for a given time. Such task belongs to the class of multi-criteria NP complex combinatorial tasks [1, 2].

The importance of decision making tasks and their complexity at different management levels necessitates the creation of information technology for decision making based on modified heuristic and evolutionary methods and algorithms.

Analysis of literary sources and problem statement

In this paper [1] the information technology for solving the problem of planning the execution of orders for production at food enterprises is proposed, based on the combination of ant colony, gray wolf and genetic algorithms. But the proposed technology can be applied to complex tasks.

In this paper [2], the authors proposed a mathematical model of the task of planning the execution of contracts and an ant colony method for its solution. But the disadvantage of the proposed approach is their focus on service enterprises, which does not allow to take into account the limitations on the volume of raw materials and packaging materials necessary for the manufacture of food products, the storage time of finished products.

The paper [3] offers information technology to solve the problem of decision support in the process of reprofiling production at virtual instrument-making enterprises, respectively, the current market demand. However, the issue of making decisions on determining the expediency of manufacturing this or that type of products and the maximum volume of production and distribution of production resources is not disclosed.

On the basis of the conducted researches of literary sources the conclusion was made about expediency of using among metaheuristic population algorithms of bats and its modification. The models presented in papers [1, 2] were taken as a mathematical model by the authors. Depending on the general situation and trends of the whole enterprise, a task can take into account a certain set or all partial criteria [1].

Bat algorithm and its modifications

The peculiarities of bats' behavior are their ability to actively collect information and make decisions very quickly. For orientation in space, bats use echolocation – they release ultrasound, which reaches the prey and is reflected back. Perfect echolocation tools, which most types of bats possess, are used by them to detect prey and obstacles, as well as to provide an opportunity to settle on the surface in the dark. Using echolocation, the bat locates the prey and attacks it. Based on the information received from the environment, the bat makes a decision about its actions in space. The algorithm can be quite effectively applied to optimization tasks and ensure the search for optimal results in less time, although it seems more complex than most other swarm intelligence algorithms [4].

The bats algorithm follows the following rules:

- all bats use echolocation to analyze distance and to distinguish between food and natural obstacles;
- the bats move randomly at the speed in position x_i with a fixed frequency f_{min}, variable wavelength λ and loudness A_0 to find the prey;
- have the ability to automatically adjust the wavelength (or frequency, as frequency = 1 / wavelength), pulse emission and pulse rate r_i $[0,1]$, depending on the distance to a particular object or prey;
- the volume varies from more positive A_0 to less constant A_{min}.

Considering that the speed of sound in air is approximately 300 m/s, the wavelength for sound with a constant frequency is determined by formula (1).

$$\lambda = \frac{v}{f} \quad (1)$$

To build a three-dimensional model of the surrounding space, the bats use the delay from signal radiation to echo detection, the difference in echo detection time in two ears. Using the built model, they determine the distance to the surrounding objects, the distance to the target, the type of extraction, the speed of its movement. In doing so, they use the Doppler effect, which is to change the frequency and wavelength of the radiation through the movement of the wave source. If the wave source moves in the environment and emits waves, the distance between the waves depends on the speed and direction of the source and receiver. If the source moves in the direction of the receiver, i.e. if the waves catch up, the wavelength decreases and vice versa - if the source moves in the direction opposite to the source, the length increases by the formula (2).

$$\lambda = \frac{2\pi(c-v)}{w_0} \quad (2)$$

where w_0 – angular frequency of the wave;

c – wave propagation speed in the environment;

v – the speed of the sound sources relative to the environment (with a "+" sign if the source is close to the receiver and with a "-" sign if it is far away).

The following values are used for algorithm operation: the wave frequencies are in the range $[f_{min}; f_{max}]$; correspond to the wavelength range $[\lambda_{min}; \lambda_{max}]$.

Let us describe the movement of bats with formulas (3-5), which are necessary for the algorithm.

$$f_i = f_{min} + (f_{max} - f_{\min})\beta \quad (3)$$

$$v_i^t = v_i^{t-1} + (x_i^t - x_*)f_i \quad (4)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (5)$$

where де $\beta \in [0,1]$ – random variable; x_* – best current solution.

At each iteration of the algorithm there is an update of the pulse amplitude and its emission. As the bat gets closer to the target, the volume of its pulses decreases (6) and the pulse frequency increases (7).

$$A_i^{t+1} = \alpha A_i^t \quad (6)$$

$$r_i^{t+1} = r_i^0[1 - \frac{1}{e^{\gamma t}}] \quad (7)$$

where α and γ are constant.

The complexity of such an algorithm directly depends on the number of people in the pack, which is used in the algorithm, the number of extrema and the dimensionality of the task.

Algorithm of bats based on Levy Flight Search Strategy (LBA)) is based on the Levy flight method, based on the trajectory of living creatures when searching for food in an uncertain and unpredictable environment. Levy's flights consist of short rapid movements and periodic long slow movements. Levy's flights reflect the trajectories of albatrosses, bees and fruit drosophila. Levy's flight behavior is the best search strategy for *N* independent researchers when searching for an object that has a random location in space, as well as when it is impossible to mathematically simulate space.

Bat movement in this algorithm corresponds to the non-Gaussian stochastic process, namely, it performs a large number of jumps in space and repeatedly changes the direction that allows you to expand the search space.

Combined with the bat echolocation function, this helps to significantly and efficiently improve the bat algorithm. The improved algorithm therefore replaces equation (5) with equation (9).

$$x_i^t = x_i^{t-1} + levy\ x\ (x_i^{t-1} - x^*) + V_i^t \qquad (9)$$

Levy's flight is used by a separate bat to search for the optimal local position, providing increased iterations of checks and optimization in the global search process. All this is designed to avoid getting into the local optimum and speed up the search for the optimal solution. The efficiency of the algorithms is evaluated on the basis of the following indicators: the time of search for the optimal schedule; the efficiency of the found plan (determined as a deviation from the evaluation of the actual plan by the target function) reducing the time of execution of orders (calculated as the difference between the actual and proposed plan).

It should be noted that the time of search for the optimal plan depends on the characteristics of computer equipment. The testing was based on statistical data on the execution of orders for previous periods, so the actual plan was taken as the one that was being executed. By results of comparison of the considered algorithms it is offered to use LBA. The disadvantages of this method include a large number of free parameters, the value of which often determines the result, on the other hand, there is no need to select these values. LBA consists in the use of the Levy Optimum method, which provides a quick search on tasks of large dimensionality.

Conclusions.

According to the results of the research, a modified LBA algorithm was proposed, which provides the formation of alternative plans for the execution of orders, taking into account the proposed mathematical model, the use of which allows to form new plans and reconfigure existing ones in a short time.

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Аннотация. *У роботі проведено дослідження алгоритмів кажанів та їх модифікацій. Проведено їх адаптацію для розв’язання багатокритеріальної задачі формування виробничих завдань та оперативно-календарних планів на харчових підприємствах. Проведений аналіз літературних джерел вітчизняних та зарубіжних авторів забезпечив підґрунтя для проведення дослідження. Апробація проводилась на основі статистичних даних по виконанню замовлень харчових підприємств. Обґрунтовано обрання алгоритму* *кажанів на основі стратегії пошуку польотів Levy, що забезпечує формування альтернативних планів виконання замовлень з урахування запропонованої математичної моделі. Використання алгоритму кажанів на основі стратегії пошуку польотів Levy для розв'язання складних багатокритеріальних задач забезпечує швидкий пошук, що є дуже важливим в реальних умовах прийняття рішень, а також може бути використаний у системах підтримки прийняття рішень.*

Ключевые слова: *планування, управління виробництвом, виконання замовлень, алгоритми, алгоритм кажанів.*

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