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ДІДЖИТАЛІЗАЦІЯ ЛОГІСТИЧНИХ ПРОЦЕСІВ З ЗАСТОСУВАННЯМ ГЕНЕТИЧНИХ АЛГОРИТМІВ

Анотація. *В сучасних умовах трансформації світового виробництва та виникнення глобальних кризових явищ використання сучасних інтелектуальних інформаційних технологій для господарюючих суб'єктів національної економіки є основним елементом розвитку як окремих систем, так і глобальних складних систем в цілому. Стратегічним орієнтиром в діджиталізації управління потоковими процесами є інноваційний підхід, який має бути системним. Запропонована в роботі концепція діджиталізації логістичних процесів реалізована на евристичних засадах, що відповідає перманентності переходу від традиційного управління складними системами до логістичного управління і визначається ступенем проникнення логістичного управління до всіх рівнів. Застосування точних методів для оптимізації транспортних перевезень не може бути реалізовано в зв'язку зі складністю врахування зовнішніх параметрів і часових обмежень, що накладаються розмірністю задачі. Розглядається евристичний підхід, до якого відноситься генетичний алгоритм.*

Ключові слова: *інноваційна логістика, оптимізація, діджиталізація процесів, генетичні алгоритми, Matlab*

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DIGITALIZATION OF LOGISTICS PROCESSES USING GENETIC ALGORITHMS

Abstract. *In the current conditions of transformation of world production and the emergence of global crises, the use of modern intelligent information technology for economic entities of the national economy is a key element in the development of both individual systems and global complex systems as a whole. A strategic guideline in the digitalization of flow control is an innovative approach, which should be systematic. The proposed concept of digitalization of logistics processes is implemented on a heuristic basis, which corresponds to the permanence of the transition from traditional management of complex systems to logistics management and is determined by the degree of penetration of logistics management to all levels. The use of precise methods to optimize transportation cannot be implemented due to the difficulty of taking into account the external parameters and time constraints imposed by the dimension of the problem. The heuristic approach to which the genetic algorithm belongs is considered.*

Keywords: *innovative logistics, optimization, digitalization of processes, genetic algorithms, Matlab*

Introduction. At present, logistics is one of the fastest growing areas of productive activity. This tendency is also fully observed in the sphere of logistics services. As an example, we can cite the United States, where the turnover of logistics services is about 40 billion dollars.

On the basis of innovative transformations of the logistics information infrastructure, management tools are developing, new logistics concepts are being developed, such as "Party Logistics"[1], which are based on determining the level of involvement of independent companies (logistics providers / operators) to solve business problems of the customer.

The optimization tasks of transport logistics are not amenable to a quick and effective solution. Modern results of research on methods of solving the main problem of routing (VRP - Vehicle Routing problem), include a variety of mechanisms for finding and improving an acceptable solution [2]. VRP belongs to the class NP - complex problems. For small dimensions, integer linear programming methods are used, for large dimensions - metaheuristics, which have become widely used in practice. Within the framework of the second direction, a hybrid genetic algorithm (GGA) is proposed, which differs from the classical genetic algorithm using the apparatus of the theory of fuzzy sets (FST) to regulate the size of the initial population.

Research methodology. Classical algorithms do not have the possibility of parallelization and have an exponential increase in execution time from the dimension of the problem. That is, the number of mathematical actions (commands) increases exponentially, and the development of processor elements (increasing clock speed, reducing the number of clock cycles of execution of commands, delay in retrieving data from memory) does not compensate for the growing (increasing the size of the problem) needs of classical algorithms. Accurate methods of solving transport problems (TP) help to find solutions only for problems with a small number of customers. To solve large-scale problems, accurate methods are ineffective due to their large time costs. However, right now we need effective algorithms for solving large-scale problems, as currently visible processes of globalization in the economy. This leads to the need to plan transport operations with a large number of customers, ie to a larger vehicle. Thus, the solution of large vehicles is an urgent task. One of the classes of vehicles is a vehicle with a time limit, this class of tasks is difficult to solve, but necessary and widely used in practice. The time-limited TP model describes: bank and postal deliveries, transportation of people, collection of industrial and household waste, delivery of products, delivery of fuel and materials to enterprises.

The scheme for the implementation of management decisions in logistics is shown below (Fig. 1).

Figure 1 - Implementation of management decisions in logistics

This approach can be applied using two known aspects: the first aspect is fuzzy systems to describe the input variables to solve the problem of system operation in conditions of economic risk and technical uncertainty; the second aspect is genetic algorithms to perform the process of optimizing a system operating in the above conditions. Evolutionary calculations are used to provide a general description of search, optimization, or learning algorithms based on formalized principles of the natural evolutionary process. Evolutionary methods are designed to find the desired solutions and are based on a statistical approach to the study of situations and iterative approximation to the desired state of the systems.

In contrast to the exact methods of mathematical programming, evolutionary methods allow to find solutions close to the optimal ones in a reasonable time, and in contrast to the known heuristic methods, optimizations are characterized by significantly less dependence on the features of the program. Decisions can, as a rule, generate new solutions that will follow the best features of their "ancestors". Modeling of the mutation process is used as a random element in the methods of evolutionary calculations. With its help, the characteristics of a solution can be accidentally changed,

which will lead to a new direction in the evolution of solutions and can accelerate the process of making a better solution.

Heuristic insertion methods are the best solution for limited and specific source data, as it is based on the consistent application of a comparative assessment of the quality of the lengths of each route.

Here are the four most popular heuristic algorithms [3]:

• Nearest Neighbor method;
• Nearest Town method;
• the method of the cheapest inclusion (Most Cheap Inclusion);
• the method of the minimum spanning tree (Minimum Spanning Tree).

The first of these methods is that the intermediate points are sequentially included in the route, and each subsequent point must be closest to its neighbor.

The next method is characterized by the fact that at each step of the algorithm builds a valid route for a given subset of points that have already been added to the route, and then adds another item not yet included in the route.

The third method is the method of the cheapest inclusion, at each stage of construction of algorithm the new point which is adjacent between two points already included in a route is added that leads to the minimum increase in a route and reduces lack of time.

However, each of the heuristic methods is formed on some unfounded considerations, which does not allow to fully assess the optimality of the solutions found.

Taboo search - a meta-heuristic algorithm for local search, which was proposed by F. Glover. This algorithm conducts a local search, which protects it from falling into the so-called "trap" of optimums. He achieves this by banning those movements that can return him to cyclical work. This algorithm is based on a list of taboos that is updated during each stage of the algorithm, and the choice of decision can not take any forbidden attribute. This is a very promising and reliable method of optimization for the transportation plan, but the analysis of violations does not allow to find all acceptable solutions.

The branch and boundary method is one of the most well-known return and restriction search methods. When using this method, the cost will have to be constant and clearly stated. But with a large dimension of the problem, such a method is not relevant, because it belongs to the class of exact methods, and this does not allow to find the most optimal route for the transportation plan at most existing enterprises.

The ant algorithm is a very "greedy" heuristic, where the probability of making a decision depends on the quality of the decision that was made earlier. This method is based entirely on the behavior of ants, due to their unique ability to find the shortest path from an anthill to food. When searching for the optimal route, an ant marks the path with some pheromone, and this information remains a clue for other ants from the same anthill. This method is good only when local search is used, without it, the optimal solution will not be found.

PJSC "Ukragrotechnika" was chosen as an object of the subject area, which has 7 own production facilities in the Poltava region, and a technological transport park of 6 different types. the routes are shown below (Fig. 2).

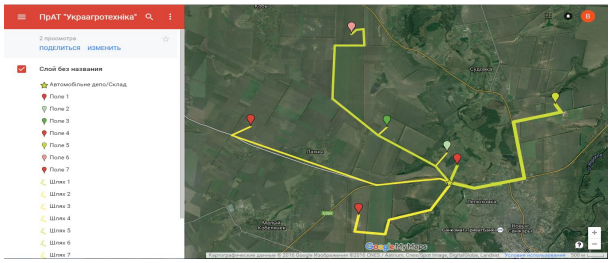

Figure 2 - Layout of production facilities

The restrictions for the genetic algorithm (GA) to work using the Matlab (ML) are as follows:

1.By the amount of harvest

x1+x2+x3+x4+x5+x6+x7=5547,23

x8+x9+x10+x11+x12+x13+x14=24770,4

x15+x16+x17+18+x19+x20+x21=60797,8

x22+x23+x24+x25+x26+x27+x28=10874,4

x29+x30+x31+x32+x33+x34+x35=8114,51

x36+x37+x38+x39+x40+x41+x42=7975,26

2.By the amount of harvest in the fields

x1+x8+x15+x22+x29+x36=101,69

x2+x9+x16+x23+x30+x37=116,35

x3+x10+x17+x24+x31+x38=163,8

x4+x11+x18+x25+x32+x39=150,8

x5+x12+x19+x26+x33+x40=113,1

x6+x13+x20+x27+x34+x41=130,39

x7+x14+x21+x28+x35+x42=107,78

3.By the inalienability of variables

x1,…, x42 ≥ 0

Therefore, based on the obtained conditions, we obtain the objective function for the ML software environment.

```
function [z] = kurs(x)
    %KURS Summary of this function goes here
    %   Detailed explanation goes here
z=6.21*x(1)+4.11*x(2)+9.50*x(3)+5.15*x(4)+6.31*x(5)+5.45*x(6)+6.32*x(7)+23.86*x(8)+18.63*
x(9)+45.05*x(10)+22.71*x(11)+27.10*x(12)+27.11*x(13)+25.74*x(14)+59.17*x(15)+45.05*x(16)
+109.69*x(17)+55.23*x(18)+67.19*x(19)+67.22*x(20)+63.83*x(21)+11.08*x(22)+8.27*x(23)+19
.05*x(24)+9.48*x(25)+12.67*x(26)+12.16*x(27)+11.29*x(28)+8.60*x(29)+5.70*x(30)+14.79*x(3
1)+7.13*x(32)+8.73*x(33)+8.80*x(34)+8.76*x(35)+8.53*x(36)+5.65*x(37)+13.70*x(38)+7.42*x(
39)+8.66*x(40)+8.98*x(41)+8.69*x(42);
    end
```

The calculation results are shown in the table. To verify the adequacy of GA application for the digitalization of logistic processes, the results obtained were compared with classical methods (tab. 1).

Table 1

Comparative analysis of calculation results

Initial cost	GA optimization	Percentage of cost reduction
100790,89 грн.	55046,1 грн.	49%

Conclusions. The main advantage of using evolutionary algorithms in general and genetic algorithms in particular when solving optimization problems is their ability to operate with a variety of solutions - a population, which allows reaching a global extremum without getting stuck in local ones. In this case, information about each individual of the population is encoded in the chromosome (genotype), the optimal solution (phenotype) is obtained after the implementation of the evolution process (selection, crossing, mutation) after decoding. Evolutionary algorithms provide huge materials for further research due to the presence of a large number of modifications and parameters of their work. It should be noted that the efficiency of the GA operation strongly depends on the parameter settings. But this does not diminish the importance of GA as one of the most researched and developing algorithms for global direct search optimization. Thus, the digitalization of logistics

processes allows us to solve several cases of problems: automation of processes, improving the quality of delivery, reducing costs, improving the shopping experience. Adequate prioritization allows you to define metrics that can be used to judge the success of digitalization. For the purpose of "quality improvement", this is, for example, an increase in the number of orders delivered on time and a% of positive feedback; to "cut costs" - reduce idle runs; for customer loyalty - an increase in the NPS index (Net Promoter Score or Customer Loyalty Index - the percentage of buyers who are ready to recommend a brand), repeat purchases and redemption of orders; for automation - reducing the time spent on completing tasks.

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