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INTELLECTUAL CONTROL OF LOGISTIC PROCESSES USING GENETIC ALGORITHMS

Abstract. Global business digitalization entails the automation of a large number of business processes, both key and auxiliary. This trend is becoming a defining factor in the global BPM market. Intelligent systems for automating business processes cover not only the corporate segment of large corporate business, but quickly penetrate into medium-sized businesses and find application in government agencies. 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: BPM-solutions, Matlab, intelligent control systemsб innovative logistics, optimization, digitalization of processes, genetic algorithms

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.

Based on the innovative information logistics infrastructure, management tools are being developed, new logistics concepts have been formed, which are based on determining the level of involvement of independent companies (logistics suppliers / operators) in solving customers' business problems. He now allocates 1PL-, 2PL-, 3PL-, 4PL- and 5PL logistics. Level 5PL (Fifth Party Logistics) provides support for advanced network computing.

Distributed according to the classification of logistics operators in the context of supply chain management.

- 1PL - autonomous logistics, in which all operations are performed by the customer;
- 2PL involves the involvement of a third party to perform certain types of work;
- 3PL provides for the use of subcontractors;
- 4PL solves the problem of supply chain formation, planning, management and monitoring of processes in logistics organizations.
- 5PL provides the organization of logistics outsourcing, using the global information space.

The activity of 5PL-provider (operator) is based on a complex of modern information technologies.

Thus, the 5PL operator controls the main flow of information about orders, resources, plans and the actual state of the transport network. Models of interactive planning management within 5PL are considered in [2].

5PL-provider is a logistics outsourcer that provides a full range of services through the use of global information technology space. We can say that this is a so-called "virtual" logistics partner, in whose hands all the information about the logistics capabilities of market participants and high-tech IT products that allow you to build the most optimal supply chain. The European Union is actively funded from the budget of the new global development of IT technologies in the field of logistics. One of the potential results of this process could be a unified information logistics network throughout the European Union. In Ukraine, start work on the introduction of a new level of logistics services 5PL, which will allow it to become one of the first countries in the world in this direction, as it occupies one of the leading positions in the world in the level of IT professionals.

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 [3]. 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.

Basic material and results

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).

Fig. 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 [4]:

• 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 [5]. 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.

A genetic algorithm is a heuristic algorithm for solving optimization problems using mechanisms that mimic biological evolution. In the case of a genetic algorithm, evolution means the evolution of a population of individuals (chromosomes) -solutions, the adaptability of each of which is determined by the value of the objective function corresponding to this solution. In the simplest case of the canonical genetic algorithm, the

simulation of such evolution is reduced to the simulation of the emergence of new offspring (new solutions) based on the crossing of parental individuals (old solutions), the simulation of the selection of the most adapted individuals (rare random changes of decisions). The correspondence of the terms of the evolutionary and mathematical models is shown in table 1.

Table 1 – **Correspondence of terms of evolutionary and mathematical models**

Evolutionary model	Mathematical model
chromosome	Solution, object, string, sequence
gene	Variable, parameter, characteristic, attribute
allele	The value of the fragment of the encoded parameter
locus	The fragment number of the coded parameter
genotype	The set of coded solutions of the solution space problem
phenotype	Many solutions to the problem
Individual, individual	object, system
suitability, suitability	Quality, optimality
Fitness - function	Target function
population	Many solutions
generation	Iteration of the evolutionary algorithm

This algorithm uses a single-point crossover operator. Then the procedure for executing the crossover operator can be described as follows:

Step 1 - determine the number of chromosomes involved in the operation of crossover. In this modification of GA involved two chromosomes, ie $h = 2$.

Step 2 - select from the population a given number of solutions (either in a probabilistic manner or based on the value of the objective function).

Step 3 - randomly select the crossingover point in the selected chromosomes.

Step 4 - paste by copying the segments located at the breakpoints, in other selected solutions.

Step 5 - calculate the correctness of the received decisions, removal of incorrect decisions, if any.

Step 6 - calculate and estimate the value of the objective function for new solutions and include them in the current population.

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).

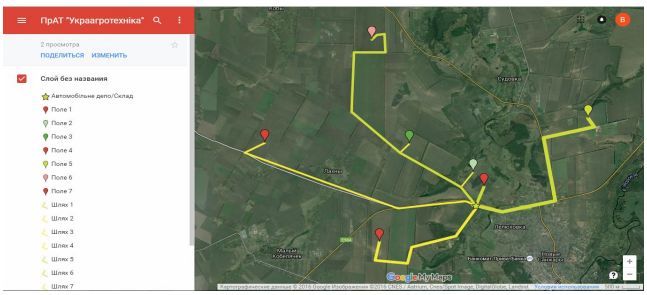

Fig. 2. Layout of production facilities

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(31)+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 (tabl. 2).

Table 2 – **Comparative analysis of calculation results**

Initial cost	GA optimization	Percentage of cost reduction
100790,89 UAH	55046,1 UAH	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.

The rapid development of the digital economy requires the appropriate development of information systems (IS) and information technology (IT), changes the direction of government strategy to overcome the current challenges of building relationships with global IT giants (Google, Apple, Facebook and Amazon), whose total capitalization exceeded GDP of many developed countries of the European Union. For Ukraine there is a question of choice of priorities, which requires extremely rapid transformation of the traditional economy into its traditional paradigm to modern information intelligent digital economy, which provides a synergistic effect of building the basis of "digital economy", "knowledge economy", "information society". In this context, the process of "consumption" of IT products becomes more significant. That is, not only to create powerful IT solutions for other countries, but also to implement modern IP and IT in national manufacturing sectors. In addition, the analysis of deep trends in energy and raw materials geopolitics shows a sharp increase in demand for energy, natural resources and food, which will increase tensions through access to these resources. Producers and consumers of these resources are complex geographically distributed systems (COTDS) or - business entities for which the task of managing large pools of resources (labor, financial, material, etc.) are the most relevant and significant -icant.

The research results presented in this paper are the basis for the formation of models and algorithms for optimizing the management of complex geographically distributed systems. The developed information technologies allow to solve a very complicated task of coordination of the three-level organizational system of COTDS, as this problem is significantly complicated by the need to harmonize the criteria of COTDS in general with the criteria of its individual components, which in turn are complex systems. In addition, these IITs can be applied autonomously in the structural units of vertically integrated entities as a basis for federal DSS and integrated into existing ERP and BPM systems on the horizon of strategic management. As a promising area of use of these IITs can be considered the possibility of their implementation within the concept of Blockchain, which is the basis of the concept of distributed data management systems.

REFERENCES

1. Skakalina, E. (2019), "Optimization model of logistic processes in business entities" in Bezpartochnyi, M. & Britchenko I. (Ed.), Conceptual aspects management of competitiveness the economic entities, Higher School of Social and Economic in Przeworsk, Poland, pp. 240-249.
2. Bronstein, E.M. Deterministic optimization problems transport logistics / EM Bronshtein, TA Zaiko // Automation and telemechanics. - 2010. - №10. - P. 133-147.
3. Lourenço H. R., Martin O., Stützle T. Iterated local search // Handbook of Metaheuristics: International Series in Operations Research & Management Sci. – Norwell: Kluwer Academic Publishers, MA, 2002. – 57. – P. 321–353.
4. Papacostas C. S., Prevedouros P. D. Transportation Engineering and Planning / 3-rd edition. – Prentice Hall, 2001. – 685 p.
5. E. Skakalina. Application of ant optimization algorithms in the solution of the routing problem / Elena Skakalina // Control, navigation and communication systems.- 2019. - Volume 6 № 58. - P.75-83. DOI: 10.26906 / SUNZ.2019.6.075.

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Інтелектуальне управління логістичними процесами з використанням генетичних алгоритмів

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Анотація. Цифровизация глобального бізнесу передбачає автоматизацію великої кількості бізнес-процесів, як ключових, так і допоміжних. Ця тенденція стає визначальним фактором на світовому ринку BPM-рішень. Інтелектуальні системи автоматизації бізнес-процесів охоплюють не тільки корпоративний сегмент великого корпоративного бізнесу, а й швидко проникають в середній бізнес і знаходять застосування в державних структурах. Стратегічним орієнтиром у цифровізації управління потоками є інноваційний підхід, який повинен бути систематичним. Пропонована концепція цифровізації логістичних процесів реалізується на евристичної основі, що відповідає сталості переходу від традиційного управління складними системами до управління логістикою і визначається ступенем проникнення управління логістикою на всі рівні. Використання точних методів для оптимізації транспортування не може бути реалізовано через складність обліку зовнішніх параметрів і часових обмежень, що накладаються розміром проблеми. Розглянуто евристичний підхід, до якого належить генетичний алгоритм.

Ключові слова: BPM-рішення, Matlab, інтелектуальні системи управління, інноваційна логістика, оптимізація, цифровизация процесів, генетичні алгоритми