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On efficiency of methods and algorithms for solving optimization problems considering objective function specifics*

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К вопросу эффективности методов и алгоритмов решения оптимизационных задач с учетом специфики целевой функции***

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Introduction. The estimation of efficiency of methods and algorithms for solving optimization problems with a vector criterion and a set of nonlinear constraints is considered. The approach that allows proceeding to an optimization problem with a single objective function (i.e., an unconditional optimization problem) after equivalent transformations is described. However, the objective function obtained in this way has properties (nonlinearity, multimodality, ravine, high dimension) that do not allow classical methods to be used to solve it. The presented work objective is to develop hybrid methods, based on combinations of the algorithms inspired by wildlife with other approaches (gravitational and gradient) for the solution to this problem.

Materials and Methods. New methods to solve the specified problem are developed. A computer experiment was conducted on a number of test functions; its analysis was performed, showing the efficiency of various combinations on various functions.

Research Results. The efficiency of hybrid algorithms that combine the following approaches is evaluated: genetic and immune; methods of swarm intelligence and genetic and immune; immune and swarm with gravity and gradient.

Discussion and Conclusions. The hybrid algorithms in optimization problems are studied. In particular, decisions can be made on their basis under the management of compound objects in the military and industrial sectors, in the creation of innovative projects related to the digital economy. It is established that the type of the objective function affects the result much more than the combination of algorithms.

Введение. Статья посвящена оценке эффективности методов и алгоритмов решения оптимизационных задач с векторным критерием и системой нелинейных ограничений. Описан подход, позволяющий после проведения эквивалентных преобразований перейти к оптимизационной задаче с одной целевой функцией (т. е. к задаче безусловной оптимизации). Однако полученная таким способом целевая функция обладает свойствами (нелинейность, мультимодальность, овражность, большая размерность), не позволяющими использовать для ее решения классические методы.

Цель представленного исследования — разработать для решения данной задачи гибридные методы, основанные на комбинациях алгоритмов, инспирированных живой природой, с другими подходами (гравитационным и градиентным).

Материалы и методы. Созданы новые методы для решения указанной задачи. Проведен компьютерный эксперимент на ряде тестовых функций, выполнен его анализ, показывающий эффективность различных комбинаций на различных функциях.

Результаты исследования. Оценена эффективность гибридных алгоритмов, которые комбинируют следующие подходы: генетический с иммунным; методы роевого интеллекта с генетическими и иммунными; иммунные и роевые с гравитационным и градиентным.

Обсуждение и заключение. Изучены возможности гибридных алгоритмов в оптимизационных задачах. В частности, на их основе могут приниматься решения при управлении сложными объектами в военной и промышленной сферах, при создании инновационных проектов, связанных с цифровой экономикой. Установлено, что вид целевой функции влияет на результат гораздо более существенно, чем комбинация алгоритмов.

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Ключевые слова: комбинация, гибрид, биоинспирированный алгоритм, роевой интеллект, градиентный алгоритм, гравитационный алгоритм, эффективность, сходимость.

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Introduction. A general optimization problem is multicriteria with a number of restrictions in the form of equations and inequalities. To solve a multicriteria task, the following types of algorithms are used:

- a posteriori (sequential assignment algorithms);
- aprior;
- sensing;
- adaptive;
- approximation algorithms based on estimated accuracy of Pareto frontier.

The listed approaches enable to narrow down the initial set of feasible solutions to one or several points [1, 2].

Let us identify the features of the methods mentioned above. The use of a posteriori, aprior, and adaptive algorithms reduces the initial problem with a vector criterion to the problem with a single objective function, which can be solved through bioinspired algorithms or their combinations. The sensing method requires a lot of computational resources. The approximation approach is characterized by high efficiency, which is due to the possibility of parallelizing the computational process [2].

The solution to the unconditional optimization problem is based on one of two algorithms: penalty functions and (or) sliding tolerance. Both of these approaches are well represented in [2] and [3]. The task is to find the global optimum of the unconstrained function.

Note features of the objective function which helps to describe a large class of technical and economic problems. The objective function is often non-linear, in most cases it is not differentiable, not unimodal, and it has a complex topology of the tolerance region. Therefore, to find the global optimum of the presented problem, the authors of this paper have created hybrid algorithms. At this, pairs can combine:

- two bioinspired algorithms;
- a bioinspired and a classical algorithms;
- a bioinspired algorithm and one based on physical laws.

Thus, a hybrid based on Fourier series and a firefly algorithm was proposed in [4]. In [5], gradient and immune algorithms are combined, and in [6], swarm and gravity algorithms are paired. The combination of genetic and swarm approaches [7, 8, 9] was also considered for solving various optimization problems with an objective function (including the problems of learning neural networks of various topology).

The efficiency criterion of the bioinspired algorithm should be considered the number of iterations (steps) at which:

- the algorithm finds a result close enough to the optimum,
- the number of steps (time) is acceptable,
- the required accuracy of the algorithm is provided.

Materials and Methods. The combinations of bioinspired algorithms developed by the authors [4–10] were tested on Rosenbrock, Rastrigin, Griewank, and Schwefel [2] functions. It should be noted that the combinations reinforced the advantages of each algorithm of the pair and leveled their shortcomings. For each function, the hybrid showed the best performance and accuracy compared to single algorithms. However, the hybrids that produced the most effective result on one test function work much more poorly with other test functions. This observation leads to the following conclusion: the efficiency of bioinspired algorithms and their combinations with other algorithms depends much more on the objective function than on the features of the combination of algorithms. The same conclusion can be drawn from the NFL theorem (short for “no free lunch”) [11].

Consider that it is necessary to find the global optimum of some function that has the properties described above. There is a bank of bioinspired algorithms and (or) their combinations. And there is a bank with an objective function that does not have the unimodality property, with a large number of variables and parameters. What algorithm can solve the optimization problem for this function as smoothly as possible? For what types of functions will this algorithm show the best result, and for which of them will it be inappropriate? It is obvious that it is impossible to develop such an algorithm. Algorithms may perform well on one function and be completely unacceptable for other functions.

Concerning the structure of bioinspired algorithms, it should be noted that a large number of empirical parameters used by them does not enable to evaluate the efficiency of such algorithms and their combinations in advance. (The opposite example is deterministic algorithms that successfully solve problems with linear, quadratic, strictly convex, unimodal functions).

For alternative estimates of bioinspired algorithms, public libraries with test problems are used, which allow comparing the known and new algorithms and their combinations [11, 12]. Sobolev Institute of Mathematics is one of the largest collections of test problems [12]. It presents various approaches to solving complex NP-complete optimization problems considering estimates of computational complexity. Among other libraries, narrow-focus ones can be noted: an open-source library for GAlib genetic algorithms [13]; libraries for building EAlib [14], Perl [15] evolutionary algorithms, and Java frameworks [16].

Research Results. The study on the features of genetic and population algorithms, performed by the authors, makes it possible to define the following advantages and disadvantages.

Genetic algorithms (GA) are based on the identity of the behavior principles of biological and technical systems. The GA use the principle of choosing the best decisions from the population available, which allows us to find the optimal solution to the problem. These algorithms give good diversity, as far as the information on solution point sets is processed in parallel. In these points, the optimum is based on the application of the objective function, and not on its various increments.

Ant colony optimizations simulate the principles of vital activity of the ant colony. There, the principle of autonomous functioning of each agent is combined with the activities of the colony as a whole, which allows solving rather complex optimization problems. The combination of ant colony algorithms with local search algorithms enables to quickly find the starting points of the optimum search. Such algorithms give the best results for large-scale problems. In terms of efficiency, they are very close to the problem-oriented and metaheuristic algorithms. This approach has shown good results in solving various practical tasks, for example, problems of traveling salesman, of optimal design of electronics, etc. Due to the possibility of using adjustable parameters, ant colony algorithms are applied in solving distribution and transport problems.

The following positive features of ant colony algorithms should be noted:

- for some tasks, they provide a more efficient solution than genetic ones or algorithms based on neural networks;
- the genetic algorithm stores information only about the previous generation, whereas ant algorithms store information about the entire colony, which is more efficient;
- random routing in the ant colony algorithm enables to exclude non-optimal initial solutions;
- the selection of parameters responsible for changing the optimization step enables to successfully use this algorithm in dynamic applications.

The disadvantages of ant colony algorithms include the following:

- theoretical analysis is difficult due to a sequence of random decisions, which is caused by changes in probability distributions during iterations;
- the algorithm convergence time cannot be predetermined, and to solve this problem, the ant algorithm is supplemented by local search methods;
- free parameters for work adjustment under solving a specific task are determined only experimentally.

When identifying extremes for composite multidimensional nonmonotonic functions, the swarm algorithms with equal probability determine the optimal element (an element with given properties) at any iteration. These algorithms are effectively used to optimize nonmonotonic functions in NP-complete problems, including distribution and transport ones. They are searching the only optimal element that determines the extremum (or sets of such elements). The swarm algorithm implements a search in the neighborhood of the best and selected sites in parallel. At this, it does not have any of the drawbacks of evolutionary methods, for example, it does not require a significant amount of memory to store a population of solutions.

Discussion and Conclusion. Analysis of the known hybrid algorithms has shown the following. One combination can give a good result on some test function (for example, Rosenbrock), but this hybrid will be significantly less efficient than other combinations on the other function. Hence, it is fair to say that the type of the objective function has much more significant impact on the result than a combination of algorithms. Therefore, the study of the form and type of the objective function enables to select the best combination.

References

1. Podinovskiy, V.V., Nogin, V.D. Pareto-optimal'nye resheniya zadach. [Pareto optimal problem solving.] Moscow: Fizmatlit, 2007, 255 p. (in Russian).

2. Karpenko, A.P. Sovremennye algoritmy poiskovoy optimizatsii. Algoritmy, vdokhnovlennye prirodoy. [Modern search engine optimization algorithms. Algorithms inspired by nature.] Moscow: Bauman University Publ. House, 2014, 446 p. (in Russian).

3. Agibalov, O.I., Zolotarev, A.A., Ostroukh, E.N. Uslovnaya i bezuslovnaya optimizatsiya pri reshenii bioinspirirovannymi algoritmami. [Conditional and unconditional optimization under solving bioinspired algorithms.] Intellektual'nye tekhnologii i problemy matematicheskogo modelirovaniya: mat-ly vseros. konf. [Intellectual technologies and problems of mathematical modeling: Proc. All-Russian Conf.] Rostov-on-Don: DSTU Publ. Centre, 2018, pp. 21–22 (in Russian).

4. Ostroukh, E.N., Klimova, D.N., Markin, S. Reshenie zadach biznes-prognozirovaniya na osnove ryadov Fur'ye i algoritma svetlyachkov. [Solving business forecasting problems based on Fourier series and firefly algorithm.] Sistemnyy analiz, upravlenie i obrabotka informatsii: tr. VIII mezhdunar. seminara. [System analysis, management and information processing: Proc. VIII Int. Workshop.] Rostov-on-Don: DSTU Publ. Centre, 2017, pp. 153–158 (in Russian).

5. Agibalov, O.I. Optimizatsiya mnogomernykh zadach na osnove kombinirovaniya determinirovannykh i stokhasticheskikh algoritmov. [Combination of deterministic and stochastic algorithms for multidimensional tasks optimization.] Modern High Technologies, 2017, no. 9, pp. 7–11 (in Russian).

6. Ostroukh, E.N., Evich, L.N., Panasenko, P.A. Razrabotka gibridnogo algoritma resheniya optimizatsionnykh zadach prinyatiya resheniy i upravleniya. [Development of a hybrid algorithm for solving optimization decision-making problems and control.] Iskusstvennyy intellekt: problemy i puti ikh resheniya: mat-ly konf. [Artificial intelligence: problems and solutions: Proc. Conf.] Moscow, 2018, pp. 165–168. Available at: https://docplayer.ru/74455293-Programma-konferencii-iskusstvennyy-intellekt-problemy-i-puti-resheniya-2018.html (accessed 08.02.19) (in Russian).

7. Evich, L.N., Ostroukh, E.N., Panasenko, P.A. Razrabotka gibridnogo algoritma resheniya optimizatsionnoy zadachi s nelineynoy tselevoy funktsiey. [Development of hybrid algorithm for solution of optimization problem with nonlinear target function.] International Research Journal, 2018, no. 1 (1), pp. 61–65 (in Russian).

8. Evich, L.N., Ostroukh, E.N., Panasenko, P.A. Metody resheniya zadach optimizatsii s mul'timodal'noy tselevoy funktsiey na osnove gibridnykh algoritmov.[Development of hybrid algorithm for solution of optimization problem with nonlinear target function.] Prom-Inzhiniring (ICIE-2018): tr. IV mezhdunar. nauch.-tekhn. ko [Prom-Engineering (ICIE-2018): Proc. IV Int. Sci.-Tech. Conf.] Moscow, 2018, no. 1-1 (67), pp. 61-65 (in Russian).

9. Ostroukh, E.N., et al. Issledovanie kombinirovannogo algoritma pri obuchenii trekhsloynykh neyronnykh setey razlichnoy topologii. [Investigation of a combined algorithm for learning three-layer neural networks of different topologies.] Software & Systems, 2018, vol. 31, no. 4, pp. 673–676 (in Russian).

10. Wolpert, D.H., Macready, W.G. The no free lunch Theorems for optimization. *IEEE Transactions* on Evolutionary Computation, 1997, vol. 1, no. 1, pp. 67–82.

11. Rodzin, S.I. Algoritmy biostokhasticheskoy optimizatsii: dostizheniya, problemy teorii, trudoemkost'. [Algorithms of bio-stochastic optimization: achievements, problems of theory, complexity.] IS&IT'18: tr. kongressa po intellekt. sistemam i inform. tekhnologiyam. [IS&IT'18: Proc. Congress on intelligent systems and information technologies.] Taganrog: S.A. Stupin's Publ. House, 2018, vol. 2, pp. 141–158 (in Russian).

12. Discrete Location Problems. Benchmark library. Sobolev Institute of Mathematics; Russian Foundation for Basic Research. Available at: http://www.math.nsc.ru/AP/benchmarks/index.html (accessed: 11.05.18).

13. Wall, M. GAlib: A C++ Library of Genetic Algorithm Components. Massachusetts Institute of Technology. Available at: http://lancet.mit.edu/ga/ (accessed: 08.11.18).

14. EALib: An Evolutionary Algorithms Library. GitHub Inc. Available at: http://github.com/dknoester/ealib/ (accessed: 08.11.18).

15. Merelo, J. J. Library for doing evolutionary computation in Perl. Available at: http://cpeal.sourceforge.net/ (accessed: 08.11.18).

16. Dyer, D. W. Watchmaker Framework for Evolutionary Computation. Available at: http://watchmaker.uncommons.org (accessed: 08.11.18).

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