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EFFICIENCY OF EVOLUTIONARY ALGORITHMS IN SOLVING OPTIMIZATION PROBLEMS ON THE EXAMPLE OF THE FINTECH INDUSTRY

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Summary. *The pandemic forced companies to rebuild business processes in an accelerated mode. Now they pay more attention to web products and work with customers in the virtual space [1]. The financial technology market (FinTech) is getting bigger and more diverse every day. Financial news website Market Screener reports that the global FinTech market will be worth \$26.5 trillion by 2022, with a compound annual growth rate of 6%. In Europe alone, the use of FinTech increased by 72% in 2020. The competition in this market segment is also growing. In the first eleven months of 2021, more than 26,300 startups have joined the fray, more than double the number of new entrants just three years earlier [2]. As the competition for customer engagement and loyalty heats up, FinTech players need to reach out to a much larger audience optimally distributed across ever-growing geographies. Monitoring and managing business operations is becoming increasingly complex as the number of customer accounts and financial transactions continues to grow. Therefore, more solutions are needed to address the challenges associated with financial IT. Therefore, the focus should be on algorithms and methods that help FinTech companies optimize all stages of their activities, from customer acquisition to payment processing and payout forecasting. In all aspects of a business, there is little room for errors, unexpected failures, or downtime. Performance optimization is the key to success in this industry. The explosion of activity caused by all these companies generates a huge amount of Structured and Unstructured Big Financial Data about customers and payments, as well as information about the underlying business processes [3]. The deep analytics hidden in this data can help companies optimize payment approval rates, transaction costs and reduce the risk of fraud, as well as customer retention and accelerate revenue growth. The above determines the acquisition of competitive advantages not only for FinTech corporations and companies, both regionally and globally, which*

is especially true in times of crisis. The article comprehensively explores the following topical issues: problems, features and prospects of effective optimization tasks in modern conditions, critical issues of theory and practice of Evolutionary Computations (including financial management), the specifics of effective use of Genetic Algorithms in information systems of FinTech companies. The above trends and peculiarities of the application of Evolutionary Computations in general and Genetic Algorithms in particular should be taken into account in further research and practical projects and real projects of effective implementation and use of Data Mining and Artificial Intelligence technologies in FinTech information systems. The obtained results are relevant and applicable not only for local companies та організацій, but also for international applications in the context of global, national and regional (not only economic, but also pandemic, military, natural disaster etc) crisis phenomena.

Keywords: FinTech, Optimization Problem, Evolutionary Algorithm, Big Financial Data, Data Mining.

INTRODUCTION

The FinTech industry comprises many different sectors and industries, including retail banking, acquiring banks, payments facilitators, trading platforms, crypto-currencies, P2P payments, and more. While the industry is diverse, all players have at least one thing in common: a sophisticated technology platform that processes upwards of millions of transactions daily, often with calls to third party partners in the value chain.

These platforms provide points where data can be collected, measured, and monitored for changes, anomalies, and trends that may indicate performance issues or business prospects. The implicit patterns and patterns hidden in this data should help companies optimize payment approval rates, optimize transaction costs, optimize risk management, reduce fraud risk, optimize customer base and increase their loyalty, optimize structure and accelerate revenue growth, etc. – i.e. conduct total monitoring of the optimality of all business processes of FinTech companies in 24/7/365 mode through the hybrid use of evolutionary calculations and Data Mining technologies for corporate Artificial Intelligence (AI) [4].

Given the above, it should be emphasized once again that mathematical optimization methods are widely used in solving most modern management analysis of efficiency and productivity, planning and forecasting in economics, finance and IT business. Known classical methods of multidimensional optimization, as a rule, are methods of local search, strongly depend on the choice of starting point of search and put forward a number of requirements to the type of objective function and input data, which complicates their application in practice.

However, in the context of global digitalization and heterogeneous crisis phenomena [5], especially relevant and very effective methods of solving optimization problems are Evolutionary Computation (EC), which are methods of global optimization based on probabilistic approach, do not require calculation of derivatives of the objective function and do not depend on the selection of the starting point of the search.

Evolutionary computing or evolutionary modeling is a field in artificial intelligence that uses and models biological evolution, usually to quickly solve complex applied optimization problems [6].

This term is usually used for a general description of search, optimization or learning algorithms based on some formalized principles and ideas of natural evolutionary selection.

There are different types of EC: genetic algorithms, evolutionary programming, evolutionary strategies, genetic programming, population metaheuristic methods and more. All of them model the basic principles in the theory of biological evolution - the processes of selection, mutation and reproduction. The behavior of agents is determined by the environment. A set of agents is called a population. Such a population evolves in accordance with the selection rules in accordance with the objective function, which is given by the environment. Thus, each agent (individual) of the population is assigned the value of its suitability in the environment. Only the most suitable species reproduce. Recombination and mutation allow agents to change and adapt to the environment. Such algorithms belong to the class of adaptive search engine optimization methods.

These topical methods are now successfully used in the development of many technical, managerial and financial software systems. EC is widely used to predict the development of financial markets, investments, etc. With the help of EC, many industrial and financial design solutions have been optimized and developed that have saved millions of dollars.

Summarizing, it must be pointed out that the above EC methods are commonly used to estimate and select (sub)optimal continuous parameters of high-dimensional models, to solve various NP-complete combinatorial problems, in Data Mining systems from BigData, FinTech and many other areas of management, science and technology [7].

It should be noted that when the problem cannot be solved by other, simpler optimization methods, EC can often find optimal or close solutions in a reasonable time. In this case, the volume of calculations may turn out to be large, but the rate at which it grows with an increase in the dimension of the problem is usually less than that of other known optimization methods. After computer systems became sufficiently fast and inexpensive, EC became the most important tool for finding suboptimal solutions to problems that were previously considered unsolvable in an acceptable period of time (especially in the context of Big Financial Data for the global and regional FinTech industry).

THE MAIN PART AND RESULTS

The most popular representative of EC is the Genetic Algorithm (GA). The genetic algorithm (GA) is a powerful tool for the evolutionary solution of complex problems. A genetic algorithm is a stochastic search algorithm that iteratively transforms a set of mathematical objects (population) that are encoded solutions to a certain problem. Each object (chromosome) is associated with an assessment of the quality of the solution to the problem, on the basis of which selection is performed, simulating the process of natural selection according to Darwin.

Evolution is considered one of the most powerful natural processes, which manifests itself in the creation of varieties that strive to survive in their environment by adapting to it. Thus, GA is a population of individuals, where the individual is one of the possible solutions to some given problem. An individual or decision is characterized by two components: genotype and phenotype. The genotype is the

internal structure of the solution, the way the solution is represented in the program for implementing the algorithm as a set of genes.

The phenotype is a direct domain-oriented type of solution in terms of the task. The quality of each solution can be evaluated by a utility function - a fitness function. The initial set of individuals undergoes three operations: crossover, mutation, and selection. Crossover is nothing more than the crossing of two or more individuals in order to reproduce offspring. Child solutions inherit parts of the genes from their parents. Mutation is a small, random change in the genotype of a solution. Mutation and crossover operators are needed to traverse the search space in order to find the optimal solution. Selection is a convergence regularizer of the algorithm and performs the selection of individuals among the population and the descendants obtained in the process of crossover based on the values of their fitness function.

The above evolutionary operators are repeated iteration after iteration over the current generation (solution population) until the termination condition of the algorithm is satisfied.

Thus, GA is based on modern ideas about the mechanisms of evolution and genetics. GA borrow from biology:

- conceptual apparatus;
- the idea of a collective search for an extremum using a population of individuals;
- ways of presenting genetic information;
- methods of transmission of genetic information in a series of generations (genetic operators);
- the idea of preferential reproduction of the fittest individuals.

The first and most important stage in the development of GA is the construction of the most suitable representation of the genotype - the decision structure. The solution structure should be designed in such a way that the genotype of the solution could be decoded as unambiguously as possible into the solution of the problem in order to assess its quality and validity (if there are restrictions).

At the same time, it is important that the genotype should be convenient for implementation of evolutionary operators and allow a full-fledged search over the space of solutions without complicating the dimensionality of the problem and unnecessary computational costs. In general, we can distinguish the following types of solutions representation: binary, integer, real-valued, combinatorial and tree-type.

When searching for an optimal solution, it is necessary to maintain a balance between "exploiting" the currently obtained best solutions and expanding the search space. Different search methods solve this problem in different ways. For example, gradient methods are practically based only on exploiting the best current solutions, which increases the speed of convergence on the one hand, but generates the problem of local extrema on the other hand. In the polar approach, random search methods use the entire search space, but have a low rate of convergence. In GA an attempt is made to combine the advantages of these two opposing approaches. Wherein, the reproduction and crossover operators make the search directional. The breadth of the search is ensured by the fact that the process is conducted on a set of solutions - a population and the mutation operator is used. Unlike other optimization methods, GA optimizes different areas of the solution space

simultaneously and is more adapted to finding new areas with better values of the target function by combining quasi-optimal solutions from different populations.

Thus, GA is designed to find the extremum of complex functions. The complexity of optimized function is defined by both number of variables for which optimization is performed and presence of local extrema. In optimization problems the search space can be almost limitless so it is impossible to prove that the solution found using GA is the best one. However, such a proof is usually not required, it is only important that the found solution sufficiently satisfies the meaning of the problem being solved.

Therefore, it is said that with the help of GA one can obtain a quasi-optimal solution. The general task of finding a quasi-optimal solution in different subject areas gets its own specifics, so the specific areas of using GA are very diverse.

These include:

- approximation of functions and regression analysis;
- numerical optimization;
- combinatorial optimization;
- parametric design;
- placement and scheduling tasks;
- tasks of automatic programming and testing of programs;
- engineering and technical design;
- automatic machine learning;
- automatic Data Mining in 24/7/365 mode.

In various control systems, GA is used for:

- choice of the structure and parameters of artificial neural networks;
- optimization of controller parameters (including neuron and fuzzy ones);
- design of multi-agent systems and cellular automata;
- development of game strategies;
- optimization of robot trajectories, including teaching the robot to walk.

The advantages of GA in the course of their application include:

- as an opportunity to represent the optimization problem being solved in the "black box" mode. So is the possibility of interpreting the obtained optimal solution (unlike ANN);

- GA does not involve the use of the entire problem space (because solutions are encoded into a chromosome);

- the ability to change the importance of optimization criteria or solve a multicriteria problem without changing the structure of the algorithm itself and recoding the solution;

- iteration of the optimization process (the possibility of obtaining an intermediate current result at any time and, accordingly, the possibility of interactive changes by the user in the parameters of the current optimization process);

- the possibility of obtaining an intuitively unexpected solution;

- the possibility of dynamic adaptation to a changing environment;

- lack of requirements for all information about the objective function;

- resistance to breaks and noise;

- the ability to get out of local optima;

- the possibility of parallelization and simultaneous processing of a large

number of alternative solutions;

- cost-effectiveness of setting, implementation and application;
- acceptable performance for a wide range of complex optimization problems;
- fault tolerance, tolerance for possible current search errors;
- the possibility of integration and hybridization [8] with other methods of modeling and optimization.

Among the disadvantages of GA are:

- insufficiently systematic and complete theoretical base;
- lack of guarantees in obtaining an acceptable solution for a finite period of time;
- lack of formalization of the methodology for setting the optimal parameters of GA;
- significant (and often not formalized) impact on the total (and also a time) of the necessary EC specifics of the subject area and setting the optimization problem.

Automatic adjustment of GA parameters and configuration during operation is an urgent scientific and technical task. Therefore, the implementation and testing of the algorithms indicated in this paper pursued several goals.

First, the necessity of adjusting the population size and the level of mutation in evolutionary algorithms was practically substantiated. Secondly, the dependence of the efficiency of algorithms on their configuration was shown. Thirdly, the statistics of the basic versions of GA was collected, which is necessary for the development, implementation and comparison of the effectiveness of methods for self-configuring and adapting GA parameters.

The authors have developed and researched adaptive schemes for tuning evolutionary algorithms that allow automatic adjustment of the population size and mutation rate. The algorithms also include useful modifications, including the uniform crossover operator, self-configuration, selection of training examples.

The study of efficiency on a representative set of test tasks showed the feasibility of using both individual modifications and their sets. Besides the optimization and approximation errors, criteria such as the number of objective function calculations required to obtain a solution, the complexity and time of the algorithm, as well as the complexity of the resulting solutions have been improved.

The comparison with analogues confirmed the usefulness of the developed modifications. An important feature is the reduction of the influence of the user's qualification on the course of the evolutionary process due to the adaptive self-tuning of algorithms in the course of solving the problem. The disadvantage of the approach is the need to set up new numerical parameters, which, however, is much simpler compared to the basic models of evolutionary algorithms.

CONCLUSIONS AND PERSPECTIVES OF FURTHER RESEARCH

Since practically significant optimization problems have, as a rule, high computational complexity and time limit, in the conditions of Big Data, IoT and FinTech, methods for increasing the efficiency of GA through hybridization and meta-optimization, methods for parallelizing calculations on distributed computing systems of various architectures (for example, MapReduce during cloud mood) are relevant.

The GA studies carried out by the authors make it possible to increase the

efficiency of machine learning of other complex Data Mining methods/algorithms (which, for example, include Deep ANNs in Semi- and Unstructured Big Data conditions) by automating the optimal configuration of their structures, parameters, and scenarios for their machine learning [9].

After all, today, the greatest potential and hope is placed on hybrid intelligent systems, which are a powerful tool for solving complex problems that are beyond the power of "clean" approaches. As a result of combining several technologies of artificial intelligence, a special term appeared - "soft computing". Currently, "soft computing" combines areas such as fuzzy logic, artificial neural networks, probabilistic reasoning and evolutionary algorithms. They complement each other and are used in various combinations to create hybrid intelligent systems (including in the field of FinTech). However, the effective integration of different technologies, algorithms and modes of Data Mining in one system requires unification and standardization of data representation, metadata, knowledge and metascience.

However, in fluid global crisis conditions [10], many emerging problems are reduced to problems of continuous global optimization. The features of such problems are often non-linearity, non-differentiability, multi-extremality (multimodality), ravine, absence of an analytical expression (poor formalization) and high computational complexity of the functions being optimized, high dimensionality of the search space, complex topology of the range of valid values, semistructured and unstructured input data. From the most general point of view, it is the above features of actual optimization problems that explain the lack of a universal GA for their effective solution and, on the contrary, the generation of an extremely large number of GA options, their modifications and hybridization options.

In connection with the foregoing, the actual direction of the authors' subsequent research is the analysis, testing and effective configuration of the next generation of search engine optimization algorithms, which are called differently: behavioral, intelligent, metaheuristic, inspired by nature, swarm, multi-agent, population. The last term most corresponds to the essence of these algorithms.

Population algorithms involve the simultaneous processing of several options for solving an optimization problem and are an alternative to the classical "trajectory" search GAs, in which only one candidate for solving this problem evolves in the search area. All population algorithms belong to the class of heuristic algorithms, namely, algorithms for which convergence to a global solution has not been proven, but it has been experimentally established that in most cases they give a fairly good solution.

It is in the topical problems of continuous multicriteria global optimization described above that the efficiency of such population algorithms is commensurable, and often exceeds the efficiency of already classical GAs. It is with the help of population algorithms that complex multicriteria dynamic stochastic optimization problems are successfully solved, for example, problems of computer-aided design, optimal control of dynamic systems.

Most fintech companies have been able to capture market share because they have successfully automated and modernized traditional processes that established financial institutions have been slower to implement. Using machine learning, entrepreneurial and innovative fintech StartUp's are gaining a competitive advantage

and disrupting the status quo in classical banking [11]. The above research findings in this article will enable FinTech companies to generate more accurate, objective and efficient AI at scale and with minimal cost and effort, achieve rapid success in critical sectors such as micro and macro lending, financial security and financial monitoring, transactional payment service, CRM and compliance, TQM etc.

References:

- [1] Krasnyuk, M., Tkalenko, A., & Krasniuk, S. (2021). Development of the fintech industry and fintech technologies under covid-19. ГРААЛЬ НАУКИ, (4), 68-70. <https://doi.org/10.36074/grail-of-science.07.05.2021.009>.
- [2] Anodot (2022) Payment optimization with AI-based analytics. available at: <https://www.anodot.com/blog/payment-optimization-ai-analytics/> (Accessed 01 May 2022).
- [3] Yurii Kulynych, Maxim Krasnyuk and Svitlana Krasniuk (2022). Knowledge discovery and data mining of structured and unstructured business data: problems and prospects of implementation and adaptation in crisis conditions. ГРААЛЬ НАУКИ, №12-13, квітень 2022. 63-70. <https://doi.org/10.36074/grail-of-science.29.04.2022.006>.
- [4] Krasnyuk, M. T., Hrashchenko, I. S., Kustarovskiy, O. D., & Krasniuk, S. O. (2018). Методологія ефективного застосування технологій Big Data та Data Mining як важлива антикризова складова комплексної політики. Економічні горизонти, (3(6), 121–136. [https://doi.org/10.31499/2616-5236.3\(6\).2018.156317](https://doi.org/10.31499/2616-5236.3(6).2018.156317).
- [5] Hrashchenko I. and Krasniuk S. (2015) Problems of regional development of Ukraine under globaliation process. Visnyk Mizhnarodnoho humanitarnoho universytetu. Serii: Ekonomika i menedzhment, 2015. - №11. – p. 26-32.
- [6] Ситник В.Ф., Краснюк М.Т. (2007) Інтелектуальний аналіз даних (дейтамайнінг): Навч. посібник. — К.: КНЕУ, 2007. — 376 с.
- [7] Kulynych Yu., Krasnyuk M., Tkalenko A., Krasniuk S. (2021). Methodology of Effective Application of Economic-Mathematical Modeling as the Key Component of the Multi-Crisis Adaptive Management. Modern Economics, 29(2021), 100-106. DOI: [https://doi.org/10.31521/modecon.V29\(2021\)-16](https://doi.org/10.31521/modecon.V29(2021)-16).
- [8] Гращенко І.С., Краснюк М.Т., Краснюк С.О. (2019) Гібридно-сценарне застосування інтелектуальних, орієнтованих на знання технологій, як важливий антикризовий інструмент логістичних компаній в Україні. Вчені записки Таврійського Національного Університету імені В. І. Вернадського. Серія: Економіка і управління. Том 30 (69). № 1, 2019. – Київ, 2019.
- [9] Krasnyuk, M., & Krasniuk, S. (2020). Comparative characteristics of machine learning for predicative financial modelling. Збірник наукових праць ЛОГОΣ, 55-57. <https://doi.org/10.36074/26.06.2020.v1.21>.
- [10] Hrashchenko, Iryna & Krasnyuk, Maxim & Krasniuk, Svitlana. (2020). Iterative methodology of bankruptcy forecast of logistic companies in emerging markets, taking into account global/regional crisis. Problems of systemic approach in the economy. 10.32782/2520-2200/2020-1-43.
- [11] Krasnyuk, M., & Krasniuk, S. (2021). Association rules in finance management. Збірник наукових праць ЛОГОΣ. <https://doi.org/10.36074/logos-26.02.2021.v1.01>.