

Evolutionary Optimization Strategies in Modern Computational Linguistics amid Dynamic Uncertainty, Turbulence, and Systemic Philological Risks

Svitlana Krasniuk

Kyiv National University of Technologies and Design, Kyiv

<https://orcid.org/0000-0002-5987-8681>

Abstract. *The article examines the features of the application of evolutionary optimization strategies in modern machine linguistics under conditions of uncertainty, turbulence, and systemic risks. Their capabilities in optimizing language models, natural language processing, and integration with artificial intelligence technologies are shown. The prospects for the use of evolutionary computing in modern digital philology are determined.*

Keywords: *digital philology; machine linguistics; natural language processing (NLP); optimization; evolutionary computing; genetic algorithms; evolutionary strategies; artificial intelligence*

Introduction.

Modern machine linguistics is experiencing a stage of intensive development [1], caused by the rapid complication of natural language processing tasks [2], the constant increase in the volume of unstructured text data, the spread of multilingual digital corpora and the active introduction of intelligent technologies into various spheres of social activity [3]. Modern philology is increasingly becoming an interdisciplinary field of knowledge that combines methods of linguistics, computer science, artificial intelligence, mathematical modeling and data analysis [4]. At the same time, the quality of intelligent language systems is determined not only by the perfection of the machine learning models used, but also by the effectiveness of the procedures for their tuning, optimization and adaptation to constantly changing operating conditions [5].

The development of the modern external environment, characterized by high dynamics of uncertainty, turbulence and systemic risks [6], gives additional relevance to this issue. Modern researchers are increasingly considering the evolution of socio-economic and information systems through the prism of the concepts of the SHIVA and WARMI worlds, which reflect the growing nonlinearity of processes, the instability of information flows, the acceleration of technological change, the emergence of new digital threats and the need for continuous adaptation of intelligent systems. In such conditions, traditional optimization methods increasingly demonstrate limited effectiveness due to the high dimensionality of the search space, the large number of local extrema and the complexity of modern deep learning models [7].

One of the most promising directions for solving such problems is evolutionary optimization strategies, which are a class of evolutionary computing methods based on

the principles of natural selection, adaptation and self-organization [8]. Unlike classical local optimization algorithms, evolutionary strategies are able to effectively explore complex multidimensional parameter spaces, ensuring the search for solutions close to globally optimal in the absence of a rigorous analytical model of the process under study.

The use of evolutionary strategies is of particular importance in modern machine linguistics [9], where there is a need to optimize neural network architectures, hyperparameters of language models, learning mechanisms, processing large text corpora, automatic translation, semantic analysis, knowledge acquisition and natural language generation [10]. The purpose of this article is to study the features of using evolutionary optimization strategies in modern machine linguistics, to determine their advantages, limitations and prospects for application in conditions of dynamic uncertainty, high turbulence and systemic risks of modern digital philology.

THE MAIN PART.

I. Application of evolutionary strategies in modern machine linguistics.

Modern machine linguistics is characterized by extremely high dimensionality of optimization problems. Even relatively simple text processing models contain thousands of interconnected parameters, while modern transformer architectures operate with billions of adjustable coefficients.

Evolutionary strategies allow to effectively solve a wide range of such problems.

They are primarily used for automatic selection of hyperparameters for language models. Learning speed, packet size, network depth, number of layers, activation functions, regularization parameters and many other characteristics directly affect the quality of model training. Evolutionary algorithms allow to automatically find the most effective combinations without an exhaustive list of possible options.

An equally important area is the optimization of neural network architectures. Instead of manually designing the model structure, evolutionary strategies allow to automatically generate the most effective architectures, ensuring high accuracy of natural language processing with minimal computational effort.

The application of evolutionary strategies in training large language models is of considerable interest. At different stages of training, there is a need to find an optimal balance between model quality, training speed, computing resources and power consumption of computing systems. In addition, evolutionary methods are used for automatic generation of feature dictionaries, selection of the most informative linguistic characteristics, construction of semantic representations of text, optimization of machine translation algorithms, automatic document generalization, thematic modeling and analysis of the emotional content of texts.

II. The role of evolutionary strategies in the SHIVA and WARMI worlds.

The modern digital environment is characterized by constantly changing information flows. New terms, professional vocabulary, Internet slang, new linguistic

constructions and communication methods appear every day. As a result, language models need constant adaptation to changing operating conditions.

The SHIVA world concept reflects the high rate of change, uncertainty, hyper-competition, nonlinear processes and rapid obsolescence of accumulated knowledge. The WARMI world concept complements this picture with the growing interdependence of information processes, the growing intellectualization of the digital economy and the need for highly adaptive computing systems.

In such conditions, the effectiveness of language models is determined not only by their initial quality, but also by the ability to quickly adapt to new data. It is here that evolutionary strategies demonstrate one of their most important advantages.

Thanks to population-based search, they are able to constantly adjust the model parameters, adapting them to new types of texts, changes in subject areas, the emergence of new linguistic constructs and changes in the structure of digital corpora. This adaptability significantly increases the resistance of intelligent systems to external disturbances and reduces the impact of systemic risks.

III. Integration of evolutionary strategies with modern artificial intelligence technologies.

The most promising direction of development of modern machine linguistics is the integration of evolutionary strategies with other intelligent technologies.

Hybrid models that combine evolutionary computing and deep learning demonstrate high efficiency. In such systems, evolutionary algorithms perform a global search for optimal solutions, while gradient methods provide local tuning of neural network parameters.

A promising combination is the combination of evolutionary strategies with reinforcement learning technologies. Such systems are able to simultaneously adapt the model to new data and optimize the decision-making strategy in the process of interaction with the environment.

Great prospects open up when evolutionary computing is used together with big data technologies, intelligent analytics, cloud computing, distributed computing platforms, and generative language models. Such integration allows us to significantly improve the quality of natural language processing, reduce model training time, and ensure more efficient use of computing resources.

IV. Advantages and limitations of evolutionary strategies.

Despite the obvious advantages, the use of evolutionary strategies has certain limitations.

The main advantages include high resistance to local extrema, no need to calculate derivatives, the ability to optimize complex multi-criteria functions, effective work with multidimensional search spaces, and high adaptability to changing operating conditions.

At the same time, these methods require significant computing resources when processing very large models, can be characterized by a relatively long search time for

the optimal solution, and require a competent choice of parameters of the evolutionary strategy itself. However, the continuous development of high-performance computing, cloud technologies, and specialized hardware accelerators is gradually reducing the impact of these limitations.

Current research suggests that it is hybrid intelligent systems that combine evolutionary strategies, deep learning, machine learning methods, and intelligent data analytics that will determine the further development of digital philology and machine linguistics.

Conclusions.

Modern machine linguistics is developing in conditions of high dynamics of uncertainty, technological turbulence and growing systemic risks, which requires the implementation of new intelligent optimization methods capable of functioning effectively in complex multidimensional information environments.

The analysis shows that evolutionary optimization strategies are one of the most promising areas of development of intelligent computing technologies. Thanks to the use of the principles of natural evolution, they provide an effective search for optimal solutions in the tasks of tuning language models, optimizing neural network architectures, automatic selection of hyperparameters, text analysis and natural language processing.

Evolutionary strategies acquire particular value in the conditions of the concepts of the SHIVA and WARMI worlds, where the key requirements are adaptability, stability, self-organization and the ability of intelligent systems to respond promptly to changes in the digital environment. Their integration with deep learning, generative artificial intelligence, big data analysis, and intelligent analytics technologies forms the basis of a new generation of adaptive machine linguistics systems. Prospects for further research are related to the development of hybrid intelligent models that combine evolutionary strategies, modern artificial intelligence methods, distributed computing, and self-learning language models to create highly efficient digital tools for modern philology, capable of functioning in conditions of ever-increasing information complexity.

References

1. Goncharenko S. (2025). Innovative IT technologies of computational linguistics. *Trends, Issues, and Challenges in Modern Science* : Proceedings of the 2nd International Scientific Conference (Cambridge, United Kingdom, 5 September 2025). - Lulu Press, Inc., 2025. - P. 109-113. URL: <https://test.knugd.edu.ua/handle/123456789/31072>
2. Goncharenko S. (2025). Intelligent information technologies for innovative management of advanced philology projects. *Innovations and New Directions in Scientific Research* : Proceedings of the 2nd International Scientific Conference (Manchester, United Kingdom, 20 September 2025). - Lulu Press, Inc., 2025. - P. 176-179. URL: <https://er.knugd.edu.ua/handle/123456789/31648>

3. Naumenko, M., & Hrashchenko, I. (2024). Suchasnyi shtuchnyi intelekt v antykryzovomu upravlinni konkurentnymy pidpriemstvamy ta kompaniiamy [Modern artificial intelligence in anti-crisis management of competitive enterprises and companies]. *Grail of Science*, (42), 120–137. DOI: <https://doi.org/10.36074/grail-of-science.02.08.2024.015>

4. Maxim Krasnyuk, Svitlana Krasniuk (2024). CHAPTER 6. Evolutionary technologies and genetic algorithms in machine translation. *Innovation in modern science: Education and Pedagogy, Philosophy, Philology, Art History and Culture, Medicine and Healthcare. Monographic series "European Science"*. Book 30. Part 3. 2024. pp. 91-98, Published by: ScientificWorld-NetAkhatAV, Lußstr. 1376227 Karlsruhe, Germany <https://desymp.promonograph.org/index.php/sge/issue/view/sge30-03/sge30-03>.

5. Goncharenko S. (2025). Mathematical optimization as element of innovative educational management in modern complex conditions. *Science and Global Challenges in the Modern World : Proceedings of the 2nd International Scientific Conference (Leicester, United Kingdom, 5 October 2025)*. - Lulu Press, Inc., 2025. - P. 90-94. URL: <https://er.knutd.edu.ua/handle/123456789/31667>.

6. Nevmerzhytska S. M. (2018). Formation of a strategy for the innovative development of enterprises in conditions of uncertainty. *Scientific Bulletin of the Kherson State University. Series: Economic Sciences*. 2018. Vol. 32. pp. 99-103. URL: <https://ej.journal.kspu.edu/index.php/ej/article/view/422/418>.

7. Krasnyuk M.T., Naumenko M.A. (2024). Efektyvne zastosuvannia henetychnykh alhorytmiv u vyrishenni bahatoekstremumnykh optymizatsiinykh zadach v menedzhmenti konkurentnoho pidpriemstva [Effective application of genetic algorithms in solving multi-extremum optimization problems in the management of a competitive enterprise]. *Grail of Science*, №41, June 2024, 65-73. URL: <https://archive.journal-grail.science/index.php/2710-3056/issue/view/05.07.2024/29> [in Ukrainian].

8. Araujo, L. (2009). How evolutionary algorithms are applied to statistical natural language processing. *Artificial Intelligence Review*, 28(4), 275–303. <https://doi.org/10.1007/s10462-009-9104-y>.

9. Manzoni, L., Jakobovic, D., Mariot, L., Picek, S., & Castelli, M. (2020). Towards an evolutionary-based approach for natural language processing. arXiv preprint arXiv:2004.13832. <https://arxiv.org/abs/2004.13832>.

10. Bungum, L., & Gambäck, B. (2016). Evolutionary Algorithms in Natural Language Processing. In *Proceedings of the Workshop on Natural Language Processing and Computational Linguistics*. (Доступний препринт через Semantic Scholar.) <https://www.semanticscholar.org/paper/Evolutionary-Algorithms-in-Natural-Language-Bungum-Gamb%C3%A4ck/d2424a7f83be06b3abd99485ee22f8fd90cb602c>.