

Genetic Algorithms and Evolutionary Strategies in Modern Computational Linguistics: Navigating the Uncertainty, Turbulence, and Systemic Risks of the SHIVA Concept

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Abstract. *In the conditions of high uncertainty and transformation of the modern digital environment (“SHIVA world”), traditional methods of natural language processing lose their effectiveness. The article is devoted to the application of genetic algorithms and evolutionary strategies for optimizing language models under conditions of high uncertainty (“SHIVA world”). The paper analyzes their role in text processing, annotating language corpora, and automatic selection of neural network architectures. The authors prove that the ability of evolutionary computing to self-adapt allows creating effective hybrid platforms for digital philology.*

Keywords: *machine linguistics, genetic algorithms, evolutionary strategies, natural language processing (NLP), the world of SHIVA, neural network optimization, digital philology.*

Introduction. The current stage of development of philological science is characterized by the transition to a new level of digitalization of research [1], within which artificial intelligence methods [2] become an integral tool for analyzing, modeling and interpreting language data. This direction becomes especially relevant in conditions of growing uncertainty, high dynamics of changes, turbulence of the information space and systemic risks characteristic of the modern external environment [3], which is increasingly described by the concept of the SHIVA-world. Unlike the predicted models of the VUCA- and BANI-environment, the SHIVA-world assumes the constant emergence of complex nonlinear processes, difficult-to-predict changes in language practices, the rapid evolution of digital communications, generative artificial intelligence and information ecosystems [4]. In such conditions, traditional algorithms for natural language processing (Natural Language Processing, NLP), based on static rules or fixed parameters, gradually cease to provide the necessary level of adaptability [5]. Machine linguistics requires intelligent methods that are capable of independently searching not just for effective, but for optimal solutions in vast spaces of possible options, adapting to variable data, taking into account multi-criteria tasks, and ensuring the stability of models to uncertainty [6].

One of the most promising directions for solving such tasks is genetic algorithms [7] and evolutionary strategies belonging to the class of evolutionary computation (Evolutionary Computation). These methods simulate the processes of natural selection, inheritance, and adaptation, allowing for automatic optimization of complex

computational models without the need for full knowledge of the structure of the studied task [8]. Their use opens up new possibilities in building language models, automatic knowledge extraction, optimization of neural network architectures, semantic text analysis, machine translation, automatic summarization, processing of large language corpora, and intellectual support of scientific research in the field of philology [9, 10].

That is why the main goal of this article is to investigate the possibilities of applying genetic algorithms and evolutionary strategies in modern machine linguistics, as well as to determine their role as intelligent tools for adaptive optimization of language models in the conditions of the SHIVA world.

Main Part.

Genetic algorithms as tool for intelligent optimization of language models.

Genetic algorithms are one of the most effective methods of global optimization, based on modeling the mechanisms of natural selection and evolution. Their fundamental advantage lies in the ability to simultaneously explore many possible solutions, gradually improving their quality through selection, crossover and mutations. This approach is especially needed in modern machine linguistics, since most natural language processing tasks are characterized by high dimensionality of the search space, nonlinearity of dependencies and the absence of a single optimal solution. The use of genetic algorithms allows you to automatically find optimal combinations of language model parameters, minimize classification errors and improve the quality of text information processing without the need for a full analytical description of the task under study.

Evolutionary strategies as development of adaptive optimization.

Evolutionary strategies are an independent direction of evolutionary computing, oriented primarily to the continuous optimization of the parameters of complex computational models. Their key feature is the self-adaptation mechanism, due to which the search parameters automatically change during the algorithm's operation. Such an approach significantly increases the efficiency of finding optimal solutions in conditions of uncertainty and rapidly changing data. In machine linguistics, evolutionary strategies are successfully used in tuning hyperparameters of machine learning models, optimizing neural network architectures, selecting the optimal feature space, and increasing the stability of natural language processing algorithms. Due to the ability to independently adjust the search strategy, these methods demonstrate high efficiency even in the absence of complete information about the properties of the studied language system.

Application of genetic algorithms for natural language processing.

One of the most promising areas of use of genetic algorithms is natural language processing. Modern text data is characterized by a large volume, a variety of structures

and high semantic complexity, which significantly complicates the application of traditional optimization methods. Genetic algorithms allow you to effectively solve the tasks of automatic document classification, thematic modeling, extraction of key terms, construction of semantic models and automatic text summarization. In addition, these methods provide an effective search for optimal combinations of features during the analysis of text corpora, which helps to increase the accuracy of intelligent information analysis and reduce the impact of information noise on the results of language data processing.

Evolutionary optimization of architectures of neural network language models.

The development of deep learning has led to the emergence of extremely complex language models containing millions and even billions of parameters. The choice of the optimal architecture of such systems is becoming one of the most labor-intensive tasks of modern machine linguistics. The use of evolutionary algorithms allows you to automate the process of designing neural networks, determining the most effective values of hyperparameters, the number of hidden layers, the size of internal representations and other characteristics of the model. The use of evolutionary optimization significantly reduces computational costs compared to exhaustive search of options and at the same time provides a higher quality of language models adapted to specific tasks of natural language processing.

Genetic algorithms and large language corpora.

Modern digital philology actively uses national and international language corpora containing millions of text documents of various genres and eras. The analysis of such information arrays requires intelligent methods that can effectively work with large volumes of data and detect hidden patterns. Genetic algorithms allow you to significantly improve the quality of text indexing, automatic markup of corpora, morphological and syntactic analysis, as well as semantic annotation of documents. These methods are of particular value when working with dynamically replenished language resources, where it is necessary to constantly adapt algorithms to the emergence of new language constructs, terms, and communicative practices.

Genetic algorithms in the conditions of the SHIVA world.

The modern digital environment is developing in accordance with the characteristics of the SHIVA world, which is characterized by a high rate of change, complexity of information flows, non-linearity of processes and the presence of systemic risks that are difficult to predict. Such conditions significantly complicate the functioning of intelligent natural language processing systems, since language models must continuously adapt to changes in vocabulary, the appearance of new terms, the development of generative artificial intelligence, and the transformation of digital communications. Genetic algorithms have an important advantage over traditional optimization methods due to the ability to constantly rebuild the process of finding optimal solutions according to changing operating conditions. It is their adaptability

that makes them especially promising for the development of intelligent linguistic systems of a new generation.

Prospects for the integration of evolutionary technologies and generative artificial intelligence.

The rapid development of generative artificial intelligence opens up new areas of application of evolutionary methods in machine linguistics. Genetic algorithms and evolutionary strategies can be used for automatic optimization of text generation processes, selection of the most effective language model architectures, improvement of learning mechanisms, and improvement of the quality of interaction between intelligent systems and users. The integration of evolutionary computing with large language models, intelligent data analysis technologies, machine learning and semantic knowledge graphs is especially promising. The complex use of these technologies allows for the formation of self-adapting intelligent platforms capable of functioning effectively in the conditions of a constantly changing digital language environment.

The main advantages of using genetic algorithms and evolutionary strategies.

The conducted analysis shows that genetic algorithms and evolutionary strategies have a number of fundamental advantages that determine their high demand in modern machine linguistics. First of all, these methods provide the possibility of global optimization of complex language models, work effectively with multidimensional search spaces and demonstrate resistance to local extrema. A significant advantage is their ability to adapt to changing data without the need to completely rebuild the algorithm. In addition, evolutionary computing is easily integrated [11] with modern technologies of artificial intelligence, machine learning and big data analysis, which allows to create intelligent linguistic systems of the new generation, which have high accuracy, scalability and resistance to the uncertainty of the modern digital environment.

Conclusions. Thus, modern machine linguistics develops under conditions of high uncertainty, nonlinearity and constant transformation of the digital language space, which requires the use of intelligent methods of adaptive optimization. The analysis shows that genetic algorithms and evolutionary strategies are effective tools for solving a wide range of natural language processing tasks due to the ability to perform a global search for optimal solutions, work with multi-criteria tasks and automatically adapt to changing data.

It is shown that the use of evolutionary computing significantly expands the capabilities of automatic text classification, semantic analysis, thematic modeling, ontology construction, optimization of neural network architectures, intelligent processing of large language corpora and improvement of generative language models. These technologies acquire particular importance in the conditions of the SHIVA-world, where the high dynamics of the external environment requires continuous adaptation of intelligent systems.

Prospects for further research are related to the development of hybrid intelligent systems that integrate genetic algorithms, evolutionary strategies, large language models, machine learning methods, big data analysis technologies, and semantic knowledge graphs. Such integration can form a new generation of self-adapting intelligent platforms for digital philology that provide higher accuracy, stability, and efficiency of automated natural language processing in the conditions of the growing complexity of the modern information environment.

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