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Applying Evolutionary Computing and Technologies to Textual Criticism and Source Studies in the Era of SHIVA and WARMI Philology

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Abstract. *The article considers the features of the application of evolutionary computations and evolutionary technologies in modern research in textology and source studies in the conditions of SHIVA and WARMI paradigms. The possibilities of using genetic algorithms and other methods of evolutionary optimization for text reconstruction, analysis of historical sources and intellectual processing of large text corpora are shown. The prospects of their integration with artificial intelligence and machine learning technologies in modern philology are substantiated.*

Keywords: *digital philology; natural language processing; big linguistic data; evolutionary computation; evolutionary technologies; textual criticism; source studies; language corpora; machine learning; SHIVA-world; WARMI-world.*

Introduction. Modern philology is going through a stage of deep digital transformation [1], which is accompanied by a rapid growth in the volume of text data [2], a complication of the structure of the information space [3] and a significant expansion of the source base of research. In the context of the transition of the scientific community to Digital Humanities = traditional methods of textual analysis and source studies are no longer always able to provide the necessary speed, completeness and objectivity of processing large amounts of textual information. This trend is especially noticeable in relation to large historical corpora of texts, manuscript heritage, archival collections, literary monuments and multilingual digital libraries.

Additional complexity of modern scientific activity is formed by the conditions of the SHIVA and WARMI worlds. The SHIVA concept characterizes the modern external environment as a space of high speed of change, hyper-uncertainty, intellectual complexity, multidimensional variability and increasing interconnectedness of research processes. The WARMI concept complements this characteristic by emphasizing the need for intellectual adaptation, the stability of scientific systems, interdisciplinary integration, flexibility of research approaches and the widespread use of artificial intelligence to support scientific decision-making. Such conditions significantly complicate the processes of analysis, reconstruction and interpretation of historical sources, and also require intelligent computing technologies of a new generation [4].

One of the most promising areas of modern computational philology is Evolutionary Computation [5]. These Evolutionary Computation technologies combine a wide range of global optimization methods based on modeling the processes of natural evolution [6, 7]. Genetic algorithms, genetic programming, evolutionary strategies, differential evolution, memetic algorithms and other methods allow for the effective search for optimal solutions in multidimensional spaces, where classical optimization methods are ineffective or unsuitable [8].

For modern textology, evolutionary technologies open up new possibilities for automated reconstruction of damaged texts, restoration of authorial editions of works, search for the most probable variants of the origin of manuscript traditions, optimization of algorithms for comparing texts, clustering of text corpora, and identification of authorship [9-11]. In source studies, these methods allow to significantly improve the quality of classification of historical documents, automate the detection of relationships between sources, reconstruct genealogical trees of manuscript traditions, optimize procedures for searching and analyzing archival materials [9-11], and also improve intellectual systems for supporting scientific research.

Considering the above, the main goal of this publication is to study the features of the application of evolutionary computing and evolutionary technologies in modern textology and source studies, as well as to determine the prospects for their use in the conditions of SHIVA- and WARMI-transformation of modern philological science.

The Main Part.

1) Evolutionary computing as an intelligent technology of modern philology.

Evolutionary computing is a direction of artificial intelligence, based on the use of mechanisms of natural selection, inheritance, mutation and recombination to solve complex optimization problems. Unlike traditional algorithms, oriented towards the search for a single local solution, evolutionary methods simultaneously explore many alternative options, gradually improving the quality of solutions over successive generations. For modern philology, such an approach is particularly effective, since most research problems are characterized by high dimensionality, incomplete

information, the absence of strict mathematical models and a large number of uncertainties. Under such conditions, evolutionary algorithms are able to automatically find the most probable solutions without the need for a complete enumeration of all possible combinations. Of particular importance is the ability to adapt algorithms to the variable characteristics of the data under study, which fully corresponds to the features of the SHIVA environment, which is characterized by high dynamism of information flows.

2) Application of evolutionary technologies in modern textology. Modern textology is increasingly faced with the need to analyze a huge number of manuscript sources, numerous editions of works and complex variants of textual traditions. In many cases, the researcher is forced to work with damaged documents, fragmentary texts, multiple lists of one work and a significant number of editorial changes. Evolutionary algorithms allow automating the solution of such tasks. One of the most promising areas is the reconstruction of lost text fragments. Genetic algorithms are able to generate many possible options for text restoration, evaluating each option using specially developed adaptability functions that take into account the linguistic, stylistic, grammatical and historical and cultural features of the work under study. Equally important is the use of evolutionary calculations for the automatic construction of stems - genealogical trees of the manuscript tradition. Such a task refers to NP-hard optimization problems, since the number of possible options for the origin of lists grows exponentially with the increase in the number of manuscripts. Evolutionary methods allow to effectively search for the optimal stem structure, minimizing the total number of expected changes between manuscripts. An additional direction is the optimization of methods for colonizing texts. Instead of sequentially comparing each variant, modern evolutionary algorithms are able to automatically find the most informative differences between texts, significantly reducing computational costs.

3) The use of evolutionary calculations in modern source studies. Modern source studies operate with extremely diverse types of historical documents that differ in origin, structure, language, time of creation and degree of security. Evolutionary technologies allow to significantly increase the efficiency of the analysis of such data. One of the most important directions is the automatic classification of historical sources. Genetic algorithms are able to simultaneously optimize the set of classification features and parameters of machine learning models, ensuring increased accuracy of document identification. Another important area of application is establishing the origin of documents and reconstructing historical relationships between them. The use of evolutionary strategies allows us to form the most probable models of the spread of textual traditions, the migration of documents between archives, and the formation of different editions of historical monuments. Additional opportunities are provided by optimizing the search in digital archives. Instead of traditional keyword searching,

evolutionary methods are able to form intelligent search strategies that take into account the semantic proximity of documents, historical context, thematic affiliation, and probable connections between sources.

4) Synergy of evolutionary computing, artificial intelligence, and large language models. The current stage of development of philology is characterized by the active integration of evolutionary computing with artificial intelligence, machine learning, deep neural networks, and large language models. Large language models are able to generate hypotheses for text reconstruction, while evolutionary algorithms provide intelligent optimization of the resulting solutions, choosing the most probable options taking into account a significant part of the criteria. Such hybridization of technologies allows to significantly improve the quality of text restoration, authorship identification, stylistic analysis and construction of semantic models of historical documents. The use of memetic algorithms that combine global search of evolutionary computations with local optimization of specialized language models becomes especially promising.

5) Evolutionary technologies under the conditions of the SHIVA and WARMI paradigms. Modern conditions of SHIVA require high adaptability of research systems, the ability to work with uncertain data and to quickly rebuild when the characteristics of the objects under study change. Evolutionary computing naturally meets these requirements due to its ability to continuously adapt to new search conditions. Within the framework of the WARMI concept, the importance of intellectual cooperation between humans and artificial intelligence is growing. Evolutionary technologies become a tool for supporting scientific decision-making, and not for the complete automation of research activities. The philologist maintains a leading role in the interpretation of results, the formation of scientific hypotheses and expert evaluation of the quality of reconstruction, while intelligent algorithms significantly speed up computational procedures, reduce the amount of manual work and allow the analysis of much larger data sets. Such a concept corresponds to the modern principles of Human-in-the-Loop AI and ensures the preservation of scientific credibility with the wide use of intelligent technologies.

6) Prospects for further development. The further development of this direction is connected with the formation of complex intellectual platforms of digital philology, which HYBRIDLY combine: evolutionary calculations; machine learning; deep neural networks; large language models; Big Data technologies; graph bases of knowledge; semantic networks; digital archives; intelligent expert systems. The creation of such hybrid platforms will allow us to move to a fundamentally new level of automated text analysis, reconstruction of historical documents, and intellectual support for philological research [12, 13].

Conclusions. The modern conditions of digital transformation of philology, characterized by high dynamics of information space development, growth of text data

volumes and complexity of research tasks in SHIVA and WARMI environments, necessitate the widespread use of intelligent methods of textual information analysis.

It is shown that evolutionary computing is one of the most promising areas of artificial intelligence for solving complex problems of modern textology and source studies. Their application provides effective reconstruction of texts, optimization of construction of manuscript tradition stems, intellectual classification of historical sources, automation of analysis of archival materials, improvement of methods of authorship identification and improvement of quality of processing of large text corpora.

It is established that the greatest scientific potential is possessed by hybrid models that combine evolutionary algorithms, machine learning methods, large language models, Big Data technologies and expert knowledge of philologists. Such integration ensures increased accuracy of scientific research, reduced computational costs, adaptation to conditions of high uncertainty, and the formation of intelligent systems to support scientific decision-making. A promising direction for further research is the development of adaptive evolutionary-intellectual platforms for digital philology capable of functioning under the conditions of SHIVA and WARMI paradigms, ensuring comprehensive automation of textual and source research while maintaining the leading role of human scientific expertise.

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