Optimization Algorithms and Their Characteristics in Neural Network Training for the Development of Macromodels of Electromechanical Systems

Oksana Hoholyuk
Institute of Power Engineering and Control Systems
Lviv Polytechnic National University
Lviv, Ukraine
oksana.p.hoholyuk@lpnu.ua

Yuriy Kozak
GlobalLogic
Lviv, Ukraine
yuriykozak2@gmail.com

Ivanna Vasylchyshyn
Institute of Power Engineering and Control Systems
Lviv Polytechnic National University
Lviv, Ukraine
ivanna.i.vasylchyshyn@lpnu.ua

***Abstract*— The paper presents a comparative analysis of the approaches, tasks, and methods used for developing macromodels of electromechanical system components and for training recurrent neural networks (RNNs). Analogies between these approaches are identified, providing a basis for recommendations on adapting methods from one domain to address problems in the other. The use of evolutionary algorithms, commonly employed in neural network training, is practically implemented in the structural identification of macromodels, confirming the effectiveness of the proposed approach. The prospects of applying a unified methodology for modeling complex technical systems and improving neural network training are demonstrated.**

***Keywords*— mathematical modeling, optimization algorithms, identification, neural network, evolution, genetic algorithm**

I. INTRODUCTION

In modern technical fields, there is a growing demand for models capable of accurately reproducing and predicting the behavior of complex systems, particularly electrical engineering systems. One effective approach is the development of macromodels, which simplify analysis and provide fast simulation, which is especially important for real-time applications [1]. At the same time, recurrent neural networks (RNNs) are an effective tool for processing sequential data and modeling nonlinear dynamic processes. Combining macromodeling with RNN training methods can improve prediction accuracy and simulation efficiency. Therefore, investigating analogies between optimization methods used for macromodel development and RNN training is of considerable relevance.

The development of macromodels of electromechanical systems based on the “black-box” principle and the training of recurrent neural networks (RNNs) have many common features. Both approaches involve constructing models of complex nonlinear relationships from input and output data while ensuring high accuracy and generalization capability. In both cases, optimization methods, including stochastic gradient descent (SGD), are used for model parameter tuning. Genetic algorithms, particle swarm optimization, and other optimization methods can be applied to the structural identification of macromodels and the selection of RNN architectures. At the same time, the choice of model structure significantly affects the accuracy, stability, and efficiency of subsequent parameter optimization.

Therefore, it is relevant to compare the methods and algorithms used in these two areas in order to enable the mutual application of established approaches, identify opportunities for transferring methods between them, and develop universal tools for improving the efficiency of electromechanical system macromodeling and RNN training.

Particular attention is paid to the development of macromodels using the “black-box” approach, in which the behavior of a component is described on the basis of its input and output signals without considering its internal structure or physical processes. Such models are constructed from experimental data and are particularly effective when information about the internal structure of the object is unavailable, when complex nonlinear relationships are present, or when rapid prediction of its behavior is required.

The development of macromodels based on the “black-box” principle has much in common with the training of recurrent neural networks, since both approaches are based on the analysis of input–output relationships and the use of optimization methods to minimize modeling error. Since the present study employs the “black-box” approach, the model parameters are determined from input and output data without taking into account the internal physical laws governing the system. Parametric identification is performed using optimization methods and consists in minimizing an error function between the experimental and model-generated data. The optimization criterion may be based on the mean squared error or absolute error, as well as on specialized error functions that account for the specific features of a particular problem.

II. CLASSES OF OPTIMIZATION METHODS

The optimization problem is formulated as follows:

$$\min_{\theta} E(\theta) \tag{1}$$

where $E(\theta)$ is the error function, and θ is the vector of macromodel parameters.

The following classes of optimization methods are used to solve the problem of parametric identification of macromodels: