

## О P I N I O N

on a dissertation for obtaining the educational and scientific degree "Doctor" in the professional field 5.3 "Communication and Computer Technique", doctoral program 02.07.20 "Communication Networks and Systems". Author of the dissertation: MSc. Petar Rosenov Tomov. Dissertation topic: Forecasting time series with artificial neural networks. Member of the scientific jury: Prof. Dr. Eng. Kosta Petrov Boshnakov

### **1.General characteristic of the dissertation**

The dissertation presented for defense on the topic "Forecasting time series with artificial neural networks" is 157 pages long and includes an introduction, four chapters, a conclusion, which includes contributions to the dissertation and guidelines for future research, list of publications on the topic of the dissertation, observed citations, awards, declaration of originality of results, bibliography and application with program code.

### **2.Relevance of the problem developed in the dissertation in scientific and applied science relationship**

The following goal of the dissertation is formulated: "To propose hybrid algorithms for accelerating training in artificial neural networks of the multilayer perceptron type for the aims of time series forecasting." To achieve the formulated goal, seven tasks are recorded.

Forecasting the change in values over time has been, is and will be of significant interest to business, banking, financial markets and technology, especially in the area of batch process control and predictive maintenance. Neural networks are a suitable and frequently used tool for forecasting time series.

The dissertation also develops other areas of interest from a modern scientific point of view, such as finding a global extremum, forecasting time series based on mobile distributed calculations and taking into account subjective opinions, etc.

### **3.Degree of knowledge of the state of the problem and creative interpretation of the literature**

The first chapter of the dissertation is entitled "Forecasting time series using machine self-learning". It provides a literature review on the topics: time series forecasting, with an emphasis on artificial neural networks and traditional methods for their training, heuristic optimization algorithms and calculations in a distributed environment. The chapter ends with a discussion and conclusions. The information is summarized in tabular form.

The literature review is based on 134 literature sources. After excluding from the analysis for the year of publication of the author's works, the bibliography in the period 2001-2010 includes 42% of the literature sources and the same percentage is of the literature sources that were published in the period 2011-2020.

The exposition in the first chapter and the topicality of the used literature gives me reason to believe that the PhD student is deeply acquainted with the current state of the problem treated in the dissertation.

#### **4. Correspondence of the chosen research methodology and the set goal and tasks of the dissertation work with the achieved contributions**

The second chapter is devoted to algorithms for prediction and training of artificial neural networks, and research focuses on genetic algorithms for training. The problems related to the limitations in the space of the variables are considered and a selection operator with local search, complete exhaustion and recursive descent is studied.

Incremental approximation with sinusoids and trend was investigated using the LibreOffice Calc optimizer with evolution of differences and optimization with a swarm of particles, the replacement of the activating function with a function of which the first derivative has no periodic component and no breakpoints, slowly calculated target functions and classification of user votes by the server in distributed human-computer type calculations.

The third chapter presents the architecture, modular organization and software implementation of a distributed prediction system with artificial neural networks of time series designed for implementation in mobile devices.

The architecture of the system and the modular organization of the mobile application are presented. The developed software application is for mobile devices running the Android OS operating system.

In Chapter 4, numerical tests of the algorithms in the forecasting system were performed. The effectiveness of accurate numerical and heuristic methods for training artificial neural networks with two sets of data has been studied.

It is concluded that in the case of exact numerical algorithms the classical algorithm with back propagation gives the best efficiency, for a time series with a relatively simple structure. In a time series with a much more complex structure, Resilient Propagation is the best. In heuristic algorithms, training with evolutionary strategy shows good results.

#### **5. Scientific, scientific-applied and applied contributions to the dissertation**

The dissertation contains the following important contributions:

1. To estimate the weights in artificial neural networks, the use of a genetic algorithm is proposed, which uses a new selection operator based on the creation of generations in the procedure of recursive descent.
2. An approach for calculating the coefficients of sine functions in the incremental approximation of time series based on the evolution of differences and a swarm of particles, in which a better approximation is achieved, is proposed and studied.
3. In order to speed up the learning process of the neural network, a function has been proposed as an activating function, the derivative of which has no periodic component and has no breakpoints.
4. The classification of consumer vote data is solved with self-organizing Kohonen maps.

5.A genetic algorithm for training artificial neural networks of the multilayer perceptron type with the possibility of application in a distributed environment is proposed.

6.The effectiveness of accurate numerical and heuristic methods for training artificial neural networks has been studied.

7.An application for mobile devices running the Android OS operating system has been developed, which includes a graphical user interface, background operation and a hybrid algorithm for training a three-layer perceptron.

## 6.Evaluation of the publications on the dissertation

Eleven scientific papers are attached to the dissertation, which reflect the research and developments. Two of the publications are independent and the other nine are co-authored, two of which are referenced and indexed in SCOPUS

Seven of the publications are in conference proceedings and four in journals. In six of the co-authored publications, MSc. Petar Tomov is the first author. All publications are referenced in Google Scholar.

## 7.Opinions, recommendations and notes

My remarks and recommendations are mainly intended to be useful in the future work of the doctoral student

1.In the dissertation there are terms that are the result of the literal translation of terms from English such as: moving average, magnitude of derivatives, etc. In the Bulgarian scientific literature are used respectively creeping average, size of derivatives and others.

2.It would be much clearer if instead of passages from the software in the dissertation the presentation is made with block algorithms

3.The formulation of some of the contributions is very extensive

## 8.Conclusion with a clear positive or negative assessment of the dissertation

Table 1 presents the minimum required points by groups for obtaining the educational and scientific degree "Doctor" in professional field 5.3 "Communication and Computer Technique" according to the requirements of IICT-BAS and the points achieved by MSc. Petar Rosenov Tomov. The minimum number of points (Table 1) according to the requirements of IICT-BAS on indicator A has been met, and on indicator G has been significantly exceeded.

Table 1

Group of indicators	Content	Minimum required points	Achieved points by MSc. Petar Tomov
A	Dissertation for assigning the educational and scientific degree "Doctor"	50	50
G	Sum of indicators from 7 to 9	30	109

Eleven publications have been made on the topic of the dissertation and 12 citations of dissertation publications have been noted, and some of the colleagues quoting it are well-

known names in the field of neural networks and optimization methods. MSc. P. Tomov has a sufficient number of scientific and applied contributions.

The author received an award in a competition for global scalable optimization, held as part of the International Conference on High Performance Computing, 2019.

What is stated in the opinion gives me the right to give a positive assessment of the dissertation "Forecasting time series with artificial neural networks" and to propose to the esteemed scientific jury to award the MSc. Petar Rosenov Tomov educational and scientific degree "DOCTOR" in professional field 5.3 "Communication and Computer Engineering", doctoral program 02.07.20 "Communication Networks and Systems".

Date: 13.06.2022

MEMBER

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