Opinion

on the Thesis for awarding Educational and Scientific degree PhD in doctoral program 02.07.20 "Communication networks and systems", Professional Field 5.3 "Communication and Computer Technology"

Author of the PhD Thesis:

Petar Rosenov Tomov

Theme of the PhD Thesis: **Time Series Forecasting With Artificial Neural Networks**

Reviewer:

Prof. Velislava Noreva Lyubenova, DSc

Institute of Robotics, Bulgarian Academy of Science

1. Short biographical information

Petar Rosenov Tomov graduated from the Technical University of Sofia with a bachelor's degree in Computer Systems and Technologies in 2013, and in 2015 with a master's degree in Computer and Software Engineering from the same university. He is received an award in a competition for global scalable optimization held at the International Conference on High Performance Computing, 2019.

2. General description of the submitted materials

As a member of the jury I received:

Order N⁰ 114 / 04.05.2022 of the Director of the Institute of Information and Communication Technologies (IICT)-BAS, in which I am included as a member of the scientific jury under the present procedure 2. Dissertation; 3. Abstract in Bulgarian and abstract in English; 4. Declaration of originality of the results 5. Order for completion of doctoral studies 6. Information on the fulfillment of the minimum requirements of IICT 7. List of printed scientific publications on the topic of the dissertation.

3. Relevance, purpose and tasks of the dissertation

The development of hybrid algorithms aimed at accelerating training in artificial neural networks (ANN) for time series forecasting is a current research area, given the widespread use of time series for process prediction in many areas, on the one hand , and the emphasis on artificial neural networks as one of the most promising methods of prediction, on the other.

The aim of this dissertation is to propose hybrid algorithms for accelerating learning in artificial neural networks of the multilayer perceptron type for the purpose of time series forecasting. To achieve the main goal, 7 tasks are set, which are consistently solved in the dissertation. They are mainly related to the analysis of the possibility of combining different algorithms for the

implementation of hybrid training of artificial neural networks of the multilayer perceptron type, with the acceleration of the training process as a main

problem in the practical use of artificial neural networks, with the development of software architecture for the implementation of mobile distributed computing with software implementation, etc.

4. General characteristics of the dissertation

The dissertation is structured in an introduction, a presentation of four chapters, a conclusion, a declaration of originality of the results, a list of publications on the dissertation and a bibliography. The dissertation is in the volume of 157 pages, 68 figures and 4 tables, 134 cited literary source and 1 application.

The **first chapter** provides an overview analysis and classification of widely used algorithms for training artificial neural networks. The advantages and disadvantages of exact numerical algorithms and heuristic algorithms are determined. The possibilities for training of artificial neural networks in sequential calculations, parallel calculations and calculations in a distributed environment are presented.

The **second chapter** presents the theory related to algorithms for training ANN of the multilayer perceptron type. Modifications of some of the algorithms that are applicable to time series forecasting are proposed, as follows 1) A new selection operator has been proposed and analyzed for determining the weights of ANN with a genetic algorithm, which operator is based on the creation of generations in a procedure for recursive descent. 2) For the purpose of approximating curves to multiple points, an approach for calculating the coefficients of sine functions with an optimizer based on the evolution of differences and a swarm of particles is proposed.; 3) A model of ANN training is presented, which aims to find optimal weights for a network of type three-layer perceptron; 4) An alternative derivative to the activation function in the ANN has been proposed, which shows promising results in terms of speed and accuracy.

The **third chapter** presents the software architecture, including selected algorithms and proposed modifications. Object-oriented and relational models, communication protocols and a graphical user interface are proposed for its implementation.

In the **fourth chapter** a comparative analysis of some exact numerical and heuristic algorithms is performed. Their productivity and total error are analyzed.

5. Contributions

I accept all the doctoral student's contributions, considering that 1 contribution could be presented in a shorter form, emphasizing the contribution part. In formulating contribution 2, there is a lack of logical connection between the first and second sentences.

6. Abstract and publications related to the dissertation

The presented author' summary of PhD Thesis presents reliably the content of the dissertation and complies with the requirements of ZRASRB and PP ZRASRB

The report on the fulfillment of the minimum requirements of the IICT-BAS for the educational and scientific degree "Doctor" shows that with a required minimum of 30 points, the doctoral student has 108 points on indicator G, which significantly exceeds the requirements. The publications of Mag. Tomov to 10 in number, including 2 reports from international conferences referred to in Scopus, 4 articles in journals and 4 reports from conferences referred to in Google Scholar.

7. Opinion, recommendations, remarks

I believe that the dissertation is well structured, the main results are clearly presented, and the evidence is illustrated with figures, tables, applications. The content of the dissertation meets all the requirements for obtaining the scientific educational degree "Doctor".

A lot of research work has benn done with scientific-applied and applied contributions in a current field.

I have no significant remarks on the dissertation.

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

In the dissertation work results of scientific-applied and applied character are obtained, which represent an original contribution to science.

The dissertation of mag. Tomov meets the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria, the Regulations for its implementation, the Regulations of BAS, as well as the Regulations for the Development of Academic Staff of the Institute of Information and Communication Technologies at BAS for obtaining the educational and scientific degree " doctor ".

Based on the analysis I give a positive assessment of the dissertation and propose the Scientific Jury to award the Educational and Scientific degree "Doctor" to Peter Tomov in doctoral program 02.07.20 "Communication networks and systems" in Professional Field 5.3 "Communication and Computer Technology"

09.06.2022

Sofia

На основание

ЗЗЛД