ANNOTATION

of the thesis work of Grishko Mikhail Valeryevich on the topic:

"**Construction of neural network models and algorithms for solving problems with incomplete information**",

submitted for the competition of Doctor of Philosophy (PhD) Degree on the specialty "6D070300-Information Systems

Topicality of the research topic. The development of artificial intelligence technology is an objective global technological trend, which reflects in the state policy in the field of science and technology development, in particular in the "Digital Kazakhstan" State Program. The application of neural networks in the field of financial technology (fintech) is also among the most topical applications of our time, owing to the rapid development and sophistication of financial technologies over the last decade, as well as involving the general public in more complex financial products, such as investment in financial assets.

Aim of thesis work. The construction and study of neural network models and algorithms to solve problems with the incomplete information, in particular problems of recognition and classification, as well as problems of reconstruction of dependencies in terms of empirical data.

Research objectives, realizing the goal of the thesis work.

- construction of the neural network model to solve the recognition problems with binary-data, reproducing the calculations of the correct algorithm according to the operator theory of Zhuravlev Yu. I.;

- development and study of the risk assessment approach of the securities portfolio in the terms of the use of Bayesian self-organizing maps.

Research objects. The operators of estimates calculation for the problems of recognition and classification, models of risk assessment of a portfolio of securities.

Research subject.

- Methods of the correct algorithm construction and the neural network reproduction of the calculations carried out by the correct algorithm.
- Models of Bayesian self-organizing maps, as well as their application to portfolio risk assessment.

Scientific novelty. The model of the neural network, reproducing the calculations of the correct algorithm (by Zhuravlev) was formed for the first

time in this work, the conditions for the tasks accuracy, for which the correct algorithm can be made, are defined.

The Bayesian self-organizing maps were applied for the first time to the problem of assessment of securities portfolios risk.

Basic Clause. on Defense

- conditions for the algebra correctness of recognition algorithms with μ-operators for calculation of evaluations over the set of recognition problems with binary information are defined.
- it was shown that for any Ω-regular problem it is possible to construct a 6-level spatial multi-layer neural network which reproduces calculations carried out by the correct algorithm. One of the particularities of the constructed network is the use of diagonal activation functions, which significantly simplifies the calculations in the inner external loop of the neural network
- approach of using Bayesian self-organizing maps for more accurate risk assessment of the securities portfolio (UBSOM method) has been considered. The developed approach is based on the construction of the portfolio distribution from the joint distribution of the portfolio components, which better summarize the internal structure of the components interaction in the portfolio than methods based only on the portfolio value data.
- it is shown that the developed UBSOM model demonstrates in numerical experiments the best accuracy among the comparable methods for the long-term forecasting.

Theoretical Significance. The conditions of algebra correctness of recognition algorithms with μ-operators for calculating evaluations over the set of recognition problems with binary information are defined in the thesis work. And these conditions which are the sufficient conditions of correctness, are formulated as restrictions on the set of recognition problems (Ω-regular problems), for which a correct algorithm can be constructed. Provided that, each operator of the original family corresponds to a μ-block - spatial, three-level, multilayer neural network, which reproduces the calculations performed by the algorithm (operator) of the original family.

Furthermore, it is possible to construct a 6-level spatial, multilayer neural network that reproduces the calculations performed by the correct algorithm

taking into account this result for any Ω-regular problem. One of the particularities of the constructed network is the use of diagonal activation functions, which noticeably simplifies the calculations in the internal external loop of the neural network.

Practical significance of the work. At the same time, concerning the practical aspect of the application of neural networks for the solution of the applied problem, the thesis work considers the approach of using Bayesian self-organizing maps for a more accurate risk assessment of the securities portfolio (UBSOM method). This method can also help to overcome the assumption of the normality of the classical Markowitz model and replace the Gaussian distribution with a mixture of Gaussians, which better corresponds to the real portfolio distributions.

The developed approach is based on the construction of the portfolio distribution from the joint distribution of portfolio components, which better reflects the internal composition of the components interaction in the portfolio than methods based only on portfolio value.

At the same time, the developed UBSOM model demonstrates in numerical experiments the best accuracy among comparable methods for long-term forecasting. It is related to the fact that the developed approach more accurately described the nature of the distribution of portfolio value gains than the alternative parametric and non-parametric methods. The point is that we approximate the distribution in multidimensional space, while the direct estimation of portfolio value gains provides the one-dimensional distribution. The transformation of vectors of financial instrument value gains into the one-dimensional portfolio value gains results in a loss of detailed information on the multivariate distribution, which influence on the actual risk of the portfolio.

The advantages of the UBSOM model have been confirmed by the results of computational experiments carried out on the basis of securities value data on the Russian and US stock markets.

The volume and structure of the thesis consists of an introduction, 3 chapters, conclusion and list of references. The total volume of the dissertation is 64 pages, 11 figures, 1 table. The list of the used literature consists of 65 sources. In the introduction the urgency of the chosen topic of the dissertation work, aims and objectives of the research, a brief overview of the obtained results, their scientific novelty and significance are substantiated.

The current state of the art of the algebraic approach to solving recognition and classification problems, outlining the principles of theory of Zhuravlev Y. I. and the theory of algorithms for computing valuations are set out in the **first Chapter**. The overview of methods for the risk assessment of a securities portfolio and the principles of the Bayesian self-organising map model is also provided in this Chapter.

The second chapter is devoted to construction of a spatial neural network model for recognition and classification tasks. The definition of recognition and classification problem is discussed in detail in this document, the gradual construction of spatial neural network model for recognition and classification tasks is considered, in particular the construction of 3-level spatial neural network model (-block) for M recognition model is considered.

The Bayesian neural network model for portfolio risk assessment problem is considered in the **third Chapter**. The provisions and features of the UBSOM model of securities portfolio risk estimation and prediction based on the synthesis of multivariate joint distribution of portfolio components are outlined here. In addition, the description of computational experiments conducted and analysis of their results are provided, the question of UBSOM application to data on financial instruments of the US and Russian stock markets is considered.

The main results and conclusions of the thesis work is provided in the Conclusion.

Level of accuracy and results of approbation. The results provided in the dissertation work were discussed at scientific seminars of the Information systems department at Al-Farabi Kazakh National University and the Institute of Information and Computing Technology, and reported at international conferences:

1. 8th International Conference on Computational and Financial Econometrics (CFE 2014), University of Pisa, Italy, 6 – 8 December 2014
2. Conference on Business Analytics in Finance and Industry, University of Chile, Chile, 6-9 January 2014
3. International Conference on Fuzzy Theory and Its Applications (iFUZZY2014), 2014
4. 2013 International Conference on Fuzzy Theory and Its Applications (iFUZZY), 2013
5. 11th International Conference on Application of Fuzzy Systems and Soft Computing, 2014

On the subject of theses have been published 7 following articles:

1. Dyusembaev, A.E., Grishko, M.V. Construction of a Correct Algorithm and Spatial Neural Network for Recognition Problems with Binary Data. Comput. Math. and Math. Phys. 58, 1673–1686 (2018). https://doi.org/10.1134/S0965542518100068 **(IF=0.675, CiteScore rank =35, Q3 Scopus)**
2. Dyusembaev, A.E., Grishko, M.V. On Correctness Conditions for Algebra of Recognition Algorithms with μ-Operators over Pattern Problems with Binary Data. Dokl. Math. 98, 421–424 (2018). https://doi.org/10.1134/S1064562418060078 **(IF= 0.619, CiteScore rank =66, Q2 Scopus)**
3. Dyusembaev, A.E., Grishko, M.V. Conditions of the correctness for the algebra of estimates calculation algorithms with μ-operators over a set of binary-data recognition problems. Pattern Recognit. Image Anal. 27, 166–174 (2017). https://doi.org/10.1134/S1054661817020043 (**IF= 0.260, CiteScore rank =49, Q3 Scopus**)
4. Grishko M.V., Murzakhmetov A.N. Making investment decisions based on econometric analysis in the conditions of Kazakhstan stock market // Bulletin of National academy of sciences of the Republic of Kazakhstan, Iss. 2, Mar 2015, pp. 250-256 (**Claritive Analytics**);
5. A. Fedotov, A. Murzakhmetov, A. Dyusembaev, M. Grishko. To Analysis of the Model of Innovation Diffusion in the Social Systems under the Influence of the Media and Interpersonal Communication // Information, International Information Institute, volume 21, issue 3, 1187-1196 (2018)
6. A.N.Murzakhmetov, A.M.Fedotov, M.B.Grishko, A.E. Dyusembaev. Modeling of distribution of innovation in socio-economic systems // News of the National academy of sciences of the Republic of Kazakhstan, physico-mathematical series, volume 6, № 316, (2017)
7. A. Dyusembaev, M. Grishko, D. Kaliazhdarov. The Conditions of Solvability of the Inverse Problem of Operator Equation for a Pattern Recognition Neurooperator Model // Australian Journal of Intelligent Information Processing Systems, volume 14, №1 (2014)