

OPINION

By Prof. Dr. Julia Dobрева, VUZF University

of a dissertation for awarding the educational and scientific degree "doctor"

by: field of higher education 3. Social, economic and legal sciences

professional direction 3.8. Economy

PhD programme *Data Science*

Author: *Vladislav Krasimirov Tanov*

Topic: Game models and modelling of time series

Supervisor: Associate professor Dr. Nikolay Netov

1. General presentation of the procedure

By order No. PD-38-597 of 03.11.2023. of the Rector of Sofia University "St. Kliment Ohridski" (SU) I have been appointed as a member of the scientific jury to ensure the procedure for the defense of a dissertation work on the topic of Game models and modeling of time series for the acquisition of the educational and scientific degree "doctor" in the field of higher education 3. Social, economic and legal sciences, professional direction 3.8 Economics, doctoral program Analytical studies on data (Data Science). The author of the dissertation is Vladislav Krasimirov Tanov - a doctoral student in a free form of study at the Department of "Statistics and Econometrics", supervised by Assoc. Prof. Dr. Nikolay Netov.

The set of materials presented by Vladislav Krasimirov Tanov is in accordance with all the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria (LAD), the Regulations for the Implementation of the LAD and the relevant Regulations of the SU, including the following documents:

- resume;
- dissertation work;
- abstract;
- a list of scientific publications on the subject of the dissertation;
- copies of scientific publications;

2. Biographical data of the PhD student

Vladislav Krasimirov Tanov was born on 16.05.1981 in Ruse. He graduated from higher education in the USA and master's program Data Analytics Engineering, George Mason University Fairfax, VA, USA in 2016. The master's degree was legalized and recognized at SU "St. Kliment Ohridski". In February 2019, he was enrolled in a doctoral course, a free form of study, in the Data Science specialty at the Faculty of Economics of the University of St. Kl. Ohridski with dissertation topic Game models and time series modeling.

He successively moved through the following professional positions as a data analyst at Microsoft (2017-2018), Amazon (2018-present). The PhD student works as an applied scientist in the field of data analysis at Amazon, USA. Scientific research in the dissertation work is tied to the direct work of the doctoral student.

3. Topic applicability

The subject of the dissertation is the search for Nash equilibrium in game theory models with specific applications in the analysis of economic and management processes. Another emphasis in the dissertation is data analysis and construction of classification models. The problems posed are current and interesting for the scientific periodical. Evidence is provided by the attached scientific publications, indexed in Scopus, on the basis of which the dissertation was built.

The dissertation successfully defends the thesis, namely, that in different conditions, an equilibrium party can be found in a competitive environment, by using stabilizing solutions for the Riccati equations to reach the Nash equilibrium. Different types of games are considered and methodologies for searching for equilibrium by solving Riccati equations are presented.

4. Knowledge of problem

In the dissertation, the doctoral student demonstrates in-depth knowledge of the problem and creatively evaluates the literary material. The presented dissertation is 137 pages long. It is properly structured and consists of an introduction, three chapters, a conclusion, references and appendices. Scientific contributions are listed after each chapter. The literature contains 88 titles, most of which were published in the last 20 years.

5. Characteristics and evaluation of the dissertation

The first and second chapters of this dissertation work are dedicated to finding equilibrium in linear-quadratic games by creating methods and algorithms for searching for stabilizing solutions of the corresponding Riccati equations.

A particularly valuable contribution of the dissertation is that these studies could be the basis for developing game models with applications in big data analysis (machine learning.).

Furthermore, the first chapter follows a linear quadratic stochastic game analyzed by Zhu and Zhang, for which an iterative method is constructed to find a stabilizing solution of a system of four nonlinear matrix equations.

The second chapter examines antagonistic games and game models on positive systems. Methods are proposed for finding a stabilizing non-negative solution of a corresponding Riccati equation.

In the third chapter, a data-oriented approach to conducting big data classification analysis is developed. An optimization model is formulated that searches for the best training set, in a specific sense, for models performing classification analysis. An algorithm is proposed to solve the optimization problem, which is applied to different sets of big data.

6. Appraisal of the publications and the personal contribution of the PhD student

The PhD student has cited 6 scientific publications, five of which are indexed in Scopus. All are co-authored. No citations are provided. All publications are in the subject of the dissertation work.

The main contributions in the dissertation work are scientific and applied and are devoted to model analyzes revealing relationships of economic agents and creating new models for data analysis in machine learning.

The research of the doctoral student Vladislav Tanov leads to finding an equilibrium in an actual stochastic game, defined and published in 2013. The proposed iterative method in the first chapter is new and finds a solution to the system of nonlinear matrix equations. The found solution equations lead to a Nash equilibrium for a linear quadratic stochastic game. The method of finding the equilibrium is innovative in the scientific literature without analogue.

In the second chapter, two approaches are proposed for calculating the equilibrium in a linear quadratic positive game. Dynamic positive systems model processes in the economy, and the fast methods proposed in the dissertation provide economic agents with information about their strategies for reaching the equilibrium point. Similar is the research on the antagonistic game presented in Section 2.1, which is related to risk analysis. Similar results have been obtained in the scientific literature on infinite non-coalition games in search of equilibrium in liberalized energy markets.

In the third chapter, the doctoral student's point of view for conducting classification analysis on data through a specific data-oriented approach is theoretically developed. The PhD student proposes models of the data leading to the construction of competitive classification models. The PhD student's achievements in the third chapter have been reported at a scientific conference and

published in a conference proceedings collection and an open access scientific journal. Both publications are indexed in Scopus.

7. Summary of the dissertation

The abstract has a total volume of 41 pages and synthesizes the dissertation work with all its elements in a structural sense, as well as the contributions of the research.

8. Remarks and questions

I find the discussion in the Conclusion and Discussion section useful. The doctoral student presents the connection between the obtained results in the dissertation work and future research on the subject. The results in the third chapter lay the foundations for more in-depth classification analysis for multi-class datasets. This analysis may be the subject of future research in the field.

I have two questions for the PhD student:

1. The contributions in Chapter Two use the properties of M-matrices. What is the main property of M-matrices with various applications in economic processes?
2. Could you name some economic processes where M-matrices are applied?

CONCLUSION

The dissertation contains scientific, scientific-applied and applied results, which represent an original contribution to science and meet all the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria (ZRASRB), the Regulations for the Implementation of ZRASRB and the relevant Regulations of SU "St. Kl. Ohridski".

The dissertation shows that the doctoral student **Vladislav Krasimirov Tanov** possesses in-depth theoretical knowledge and professional skills in professional direction 3.8. Economics by demonstrating qualities and skills for independent conduct of scientific research.

Due to the above, **I confidently give my positive assessment of the conducted research, presented by the above-reviewed dissertation work**, abstract, achieved results and contributions, and I propose to the honorable scientific jury to award the educational and scientific degree "doctor" to Vladislav Krasimirov Tanov in the field of higher education: 3. Social, economic and legal sciences, professional direction, 3.8. Economics, PhD program "Data Science".

02.12.2023

Prepared by:

Prof. Dr. Julia Dobрева