OPINION

For a competition for the academic position "Professor" SN 95/14.11. 2023.
With candidate: **Assoc. Prof. PhD Vera Angelova Angelova - Dimitrova**

From Prof. DSc Krasimira Stoilova – Institute of Information and Communication Technologies (IICT) – Bulgarian Academy of Sciences (BAS)

By order № 7 of 10.01.2024 of the Director of IICT - BAS, issued on the basis of a decision of the Scientific Council of IICT, protocol №12 of 29.11.202, I have been appointed as a member of the scientific jury for a competition to occupy the academic position of "Professor" in the field of higher education 5. Technical sciences; professional direction 5.2 „Electrical engineering, electronics and automation", scientific specialty „Application of the principles and methods of cybernetics in various fields of science" for the needs of a section „Intelligent Systems" of IICT - BAS. Only one candidate submitted documents for the announced competition - Assoc. Prof. PhD Vera Angelova Angelova - Dimitrova.

1. General description of the presented materials

Assoc. professor V. Angelova graduated from TU – Sofia as an automation engineer. She has been a PhD since 1995 and associate professor since 2005.

An official note is presented regarding the total work experience, which is 34 years, of which he worked as an associate professor for 19 years.

2. General characteristics of the scientific and scientific-applied activity

All 28 scientific publications presented are after her procedure for PhD and the competition for "associate professor". All publications are in English. Of them 5 are independent [Г4, Г9, Г10, Г11, Г13]. The general list of all publications of Prof. Angelova includes 67 titles.

Of the publications for the competition, 17 are in journals with an impact factor (IF): [B1] – [B10], [Г2 – Г5], [Г7], [Г8], [Г14]; 7 are in journals with SJR [Г1], [Г6], [Г9] - [Г13],

According to the publications submitted for the competition, the scientific interests of Assoc. Prof. V. Angelova are in the main direction:

Conditionality and sensitivity of matrix equations [B1-B10, Г1-Г3, Г5-Г11, Г13, Г15-Г18].

There are also publications in the directions:

Soft computing [Г4];

Personality and behavior in e-commerce [Г12, Г14].

3. Analysis of scientific and scientific-applied achievements according to the materials

Assoc. Prof. Angelova's scientific interests are related to solving problems from the Theory of linear control systems. Her focus is on perturbation analysis of matrix equations to investigate the conditioning and sensitivity of their solution to data perturbations. Lyapunov majorants are used in the analysis of operator equations in nonlinear mechanics problems. The joint use of Lyapunov majorants and topological fixed point principles leads to the establishment of conditions for the existence and uniqueness of solutions of equations in function spaces. Subsequently, the Lyapunov scalar and vector majorant technique was

developed for perturbation analysis of operator equations. Assoc. Prof. Angelova develops approaches based on Fréchet derivatives for deriving first-order condition numbers and perturbation limits. She derives nonlocal perturbation bounds by applying the method of equivalent Lyapunov operators and majorants combined with fixed-point principles.

SCIENTIFIC CONTRIBUTIONS

Conditionality and sensitivity of matrix equations

1. The method of Lyapunov majorants and fixed point principles are applied to obtain non-local nonlinear bounds on the error, which represents the distance between the approximate solution of the non-symmetric Riccati differential equation of reduced order /projected into a space of reduced dimension/ and the exact solution of the unscaled nonsymmetrical Riccati differential equation of full rank [B8].
2. Two approaches of nonlocal perturbation analysis are developed to study the sensitivity of the solution to perturbations in the matrix coefficients and the initial state for a nonsymmetrical Riccati differential equation [B9]. Nonsymmetric Riccati differential equations are related to linear boundary value problems in game theory, control theory, calculus of variations, theory of transport processes. They are an intermediate stage in singular perturbation approximation and control theory problems when linear transformations are applied to reduce the order of systems or to partial decomposition of systems. Two perturbation bounds are derived using Fréchet derivatives, the Lyapunov majorant method and fixed point principles. The first bound is for an integral form of the solution and is obtained for the nonsymmetric Riccati differential equation in its general form. For the second boundary, Radon's theory of equivalence of the solution of Riccati's differential matrix equation with the solution of the boundary value problem of the associated differential system is used. This avoids solving the non-symmetric Riccati differential equation and the associated divergence problems of the numerical procedure. The two bounds use existing sensitivity estimates of the matrix exponent and are alternate. The perturbation limit is important in the process of numerically solving an equation and is a tool for evaluating the robustness of the computational process. The derived narrow perturbation limits allow one to assess the accuracy of the numerical solution of the nonsymmetric differential matrix Riccati equation.
3. For the needs of the experimental analysis of perturbation bounds of Riccati's symmetric differential matrix equation known in the literature, an analytical solution of Riccati's symmetric differential equation was derived and proved [B10]. The obtained analytical solution of the equation is used in tasks related to solving Riccati's differential equation.
4. An analytical expression of the first Fréchet derivative of the function $A \rightarrow A^p$ in the point A at $p = -1/s$, where s is a natural number [Г5]. The result has a wide resonance in the world scientific field and publication [Г5] has 16 citations. As a continuation of [Г5], absolute and relative norm, mixed and component numbers of conditionality of the equation were formulated [Г8]. Condition numbers are a measure of the sensitivity of the solution to perturbations in the data and are involved in formulating perturbation bounds. According to the analysis done, for tasks where the data varies significantly in size, it is better to use relative condition numbers. In the case of a significant difference of the disturbances by components, the use of the component analysis is recommended, since the norm bounds that give a measure of the largest disturbances would be pessimistic for structured smaller disturbances. Mixed condition numbers provide more accurate estimates for problems with sparse data matrices, since round-off errors are generally not accumulated in the zero elements of the data.

5. The perturbation analysis approach is developed for singular operator matrix problems [Г2]. The result is original because for a singular operator matrix the techniques of local perturbation analysis are inapplicable because there is no inverse matrix of the singular operator matrix. Therefore, no solution error equation can be obtained. The development of the standard perturbation analysis technique is extended to the case of a singular operator matrix [Г2]. The development consists of projecting the perturbation into subspaces with $n \times n$ positive dimension. The operator matrix of the projected problem is nonsingular, which allows obtaining the solution error equation by multiplying the projected operator equation with the inverse of the nonsingular projected operator matrix.

6. New original absolute and relative condition numbers, asymptotic and nonlocal upper bounds on round-off errors, and upper bounds on residual error in solutions of matrix equations from control theory and other fields are derived [B3 – B7], [B9], [Г1], [Г3], [Г6 – Г11], [Г13], [Г17], [Г18].
   - Explicit expressions for the norm-wise, mixed and component-wise condition numbers of the complex matrix equation are obtained [B3, B6]. First order bounds for the perturbations in the computed solution are proposed, as well. The added value of the research is that the condition numbers and the local perturbation bounds proposed allow easy computable and fast estimate of the accuracy of the computed solution.
   - The effectiveness of the perturbation bounds proposed in five issues for the real and the complex equations in [B3] and [B6] is analyzed in [B1]. The results of the experimental analysis allow classifying the bounds considered with respect to closeness to the estimated quantity and comprehensive application. The observed behavior and the analyzed properties of the bounds considered hold true for every problem, which belongs to the class of the experimental models used.
   - Effective and easy computable norm-wise non-local residual bound for the computed by an iterative algorithm solutions of nonlinear complex matrix equations of second type is derived [Г7, Г16]. The added value of the research is that the bound is simple and of a practical use to assess the accuracy of the approximate solution obtained by an iterative algorithm. A comparison with a known in the literature residual bound proves the superiority of the proposed bound in terms of accuracy and sharpness.
   - For the third type of complex equations, an analysis of the efficiency and accuracy of the existing methods for evaluating the sensitivity of the solution with respect to the perturbation limits is made [B2]. The behavior and reliability of the limits proposed in 9 literary sources were investigated. Areas of their application are indicated depending on efficiency, computational difficulty, reliability and accuracy.
   - Explicit expressions for the norm-wise, mixed and component-wise condition numbers of third complex nonlinear matrix equation are obtained [B4, Г6] (18 citations). The condition numbers are used to derive upper bounds on the error in the computed solution. Using condition numbers we may estimate the level of uncertainty in the solution due to errors (measurement, modelling, round-off) in the data before applying a numerical algorithm to solve the equation. The same approach is applied for local perturbation analysis of the stochastic matrix Riccati equation with applications in finance domain [Г9].
   - An iterative algorithm for residual error bounding in the approximate solution of the fourth type of nonlinear complex matrix equation related to modeling of optimal interpolation problems is developed [B7]. The bound is determined based on nonlocal perturbation analysis, the method of Lyapunov majorants and the fixed point principle.

The residual error can be used as a termination criterion for iterative algorithms for solving equation.

- Using the above approach the residual bound is done for a fifth type of complex matrix equation in [Г3] and sixth type in [B5].
- The perturbation analysis is applied for finding norm-wise, mixed and component-wise condition numbers and based on them easy computable local bounds, as well as norm-wise non-local residual bounds for the solution to the nonlinear matrix equation (seventh type) connected to a tree-like stochastic processes [Г10, Г11]. The condition numbers allow estimating the level of uncertainty in the solution due to errors in the data when applying a numerically stable algorithm to solve the equation. Effective, easy to compute and based on the approximate solution, the residual bounds can be used as a stopping criterion for the iterative algorithm.
- Applying the local and the nonlocal perturbation analysis, based on the techniques of Frechet derivatives, the method of Lyapunov majorants and fixed point principle, local and nonlocal perturbation bounds to the nonlinear matrix Equation of eighth type are derived [Г13] .
- Residual bound for non-linear complex matrix equations of ninth type [Г17] and tenth type [Г18] has been derived using the method of the Lyapunov majorants and the fixed point principles.
- A complete perturbation analysis of the complex matrix equation of eleventh type is done [Г1]. This equation arises in control theory when solving systems of linear equations by LU decomposition. Condition numbers, local and non-local perturbation bounds are obtained. The technique used is based on Lyapunov majorants and fixed point principles.

SCIENTIFIC-APPLIED CONTRIBUTIONS

Personality and behavior in e-commerce

The relationship between emotional stability, consumer risk aversion, and consumer behavior in e-commerce was investigated [Г12, Г14]. As a result of the study, the relationship between emotional stability and consumer risk awareness on the one hand and some observed basic functionalities of online stores on the other hand was confirmed. Two regression models in the field of machine learning have been synthesized for the purpose of predicting user preferences in online shopping.

I positively assess the candidate's scientific and scientific-applied **contributions** in the presented research areas.

4. Citations

A list of 130 citations of all the candidate's publications in the contest is attached. The noted citations of the publications submitted for participation in the competition are 106. Of the citing publications, 70 are in indexed/referenced Scopus and/or Web of Science publications.

5. Fulfillment of the minimum requirements and other activities

Assoc. Prof. Angelova fulfills and exceeds in all indicators the minimum requirements for the academic position of "professor" according to the Act on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its application and the IICT

Regulations. According to IICT Regulations requirements/**performance** under individual indicators is as follows: indicator A - 50/**50**; B - 100/**240**; Г – 220/ **338.3**; Д – 120/**866**; E – 150/**250**.

Assoc. Prof. Angelova has published 3 university textbooks and 2 university teaching aids.

24 publications are visible in Scopus and its H-index is 5.

Assoc. Prof. Angelova has participated in 1 international and 4 national projects according to the attached references.

Assoc. Prof. Angelova has been an associate professor in the "Intelligent Systems" section since 2010. She has a PhD student who defended his dissertation in 2021.

She also teaches (in French) at the French Faculty of TU-Sofia and Sofia University - "Fundamentals of Statistics" and "Applied Statistics".

Assoc. Prof. Angelova has an active administrative and organizational activity - she is a member of the Scientific Council of IICT; from 2022 until now she is a scientific secretary of IICT; from 2020 until now she is a member of the BAS General Assembly; from 2009 until now she is a member of the Academic Council of the BAS Training Center.

She is a member of the Scientific and Methodological Council of the Professional Training Center of "Information Service" AD in the period 2016-2023.

She is a member of the editorial board of 3 journals: "Cybernetics and Information Technologies" with IF/SJR, of which she is the secretary since 2019; Lecture Notes in Computer Science and Technologies of IICT-BAS, ISSN 2367-8666; "Journal of Information Technology and Control" ISSN 1312-2622.

Associate Professor V. Angelova has an active scientific research, scientific-applied, teaching, expert, organizational and managerial activity, characterizing her as a highly qualified scientist with international prestige.

Conclusion. Based on the presented materials, the scientific and scientific-applied contributions, as well as the complex assessment of the other indicators of the competition, I give **a positive assessment and confidently recommend to the Honorable scientific Jury** to propose to the Scientific Council of IICT-BAS **to elect Associate Professor Dr. Vera Angelova Angelova-Dimitrova for the academic position "Professor"** for the needs of the "Intelligent Systems" section at IICT - BAS, professional direction 5.2 "Electrical engineering, electronics and automation", scientific specialty "Application of the principles and methods of cybernetics in various fields of science".

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