REVIEW

concerning a competition for the academic position of Professor in the field of higher education 5. Technical sciences, professional field 5.2. Electrical engineering, electronics and automatics, scientific specialty "Application of the principles and methods of cybernetics in various fields of science (technical)" announced in the State Gazette № 95/14.11.2023 for the needs of the section " Intelligent systems " of the Institute of Information and Communication Technologies (IICT)-BAS

Candidate: Assoc. Prof. Dr. Vera Angelova Angelova-Dimitrova

Reviewer: Prof. DSc. Velislava Noreva Lyubenova, Institute of Robotics-BAS

1. General and biographical data

By order № 7/10.01.2024 of the Director of the Institute of Information and Communication Technologies – BAS, Corresponding Member of BAS Margenov, I am included in the composition of the Scientific Jury for the above-mentioned competition with the only candidate Assoc. Prof. Dr Vera Angelova Angelova-Dimitrova.

The professional development of the candidate can be traced from the presented CV. She graduated from the 9th ESPU with teaching in French and Spanish "G. Kirkov", Sofia in 1984. In 1989, she obtained a master's degree - Electronics and Automation Engineer at Technical University (TU)-Sofia. In 1991, she completed postgraduate qualification as an engineer-specialist in applied mathematics and informatics at the Institute of Applied Mathematics and Informatics, (TU)-Sofia.

She has been a doctoral student at the Institute of Informatics - BAS since 1991, and in 1993 she defended her doctoral thesis in the field of perturbation and numerical analysis. In 2005, she acquired the academic position of "Associate Professor" (Senior Research Associate II degree) at the Institute of Information Technologies, scientific specility "Application of the principles and methods of cybernetics in various fields of science (technical)".

Assoc. Prof. Angelova's scientific and research activities took place entirely in the Bulgarian Academy of Sciences and are in the areas of numerical and perturbation analysis, matrix equations, linear multidimensional control systems, statistics, etc. In the period 1993–1995, she was a programmer at the Institute of Informatics, BAS (Institute of Information Technologies (IIT)). She was a research associate II degree for the period 1995–1997, from 1997 to 2005 a research associate I degree, and from 2005 to 2022 she was an Associate Professor at IIT-BAS (predecessor of IICT). From 2022 until now, she combines the positions of Associate Professor and scientific secretary at the same institute. She is also a member of the Scientific Council of IIKT-BAS, the Academic Council of the Center for Training at BAS and the General Assembly of BAS from 2022.

The copies of documents provided to me contain:

1. Curriculum vitae according to the European model with three appendices: Appendix 1 – Publications, all; Appendix 2 - Citations, all; Appendix 3 - Activities.
2. Diploma for the educational and scientific degree "Doctor";
3. Certificate of internship in the specialty;
4. List of scientific publications for participation in the competition, which do not repeat those submitted for the acquisition of the educational, scientific degree "Doctor" and for the academic position "Associate Professor";
5. List of textbooks and teaching aids;
6. List of citations;

7. Summaries of scientific publications for participation in the competition - in Bulgarian and English;

8. Scientific publications for participation in the competition;

9. Reference for fulfillment of the minimum requirements under Art. 2b, para. 2 and 3 of the Law on the development of the academic staff of the Republic of Bulgaria (LDASRB) and the requirements of IICT under Art. 2b, para. 5;

10. Reference for original scientific and scientific-applied contributions;

11. Declaration that plagiarism has not been proven in scientific works according to the law;

12. Certificates of participation in the implementation of projects;

13. Electronic carrier with information according to the requirements of IICT.

On the necessary documents for participation in the competition and their content, according to the normative basis of the Law on the Development of the Academic Staff of the Republic of Bulgaria (LDASRB), the Regulations for the Implementation of the LDASRB, the BAS Regulations for the implementation of the LDASRB and the Regulations for the Specific Conditions for the Acquisition of Scientific degrees and for occupying academic positions at IICT-BAS, for the terms and conditions for occupying the academic position "Professor", I have no objections. All the materials are properly formatted and arranged. The procedural requirements for announcing and participating the candidate in the competition have been met.

According to the LDASRB, candidates for the academic position of "Professor" must meet the requirements of Article 29(1):

1. To have acquired the educational and scientific degree "Doctor".
2. To have held the academic position of "Associate Professor" in the same or in another higher school or scientific organization for no less than two academic years or...
3. To have submitted a published monographic work or equivalent publications in specialized scientific publications, which do not repeat those submitted for the acquisition of the educational-scientific degree "Doctor" and for occupying the academic position of "Associate Professor".
4. To have presented other original scientific research works, publications, inventions and other scientific and scientific-applied developments or artistic achievements, which are evaluated as a whole;
5. To meet the minimum national requirements under Art. 2b, para. 2 and 3, respectively, to the requirements under Art. 2b, para. 5;
6. Not to have plagiarism or unreliability of the presented scientific data in the scientific works proven in accordance with the law.

The requirements under Article 29(1), item 1 are fully fulfilled, since with diploma № 23757/02.10.1995 Higher Attestation Commission certifies the educational and scientific degree "doctor" obtained by the candidate.

Assoc. Prof. Angelova meets the requirement of Art. 29(1), item 2, as she has held the academic position "Assoc. Profescor" since 2005. The candidate fulfills the requirement of Art. 29(1). item 3, as she presented 10 publications equivalent to a monographic work, which do not duplicate the publications for holding the academic position "Assoc. Profescor" and for acquiring the educational and scientific degree "Doctor".

Assoc. Prof. Angelova meets the requirement of Art. 29(1), item 4, as she submitted other original research works and publications, a total of 18. The candidate submitted a Certificate of fulfillment of the national minimum requirements, as well as a Certificate of fulfillment of the minimum requirements of the IICT for the academic position "Professor" .
She meets and exceeds the requirements on both references. (Table 1). Regarding the requirement of Art. 29(1), item 6, I am not aware of received reports under Art. 4 para. 11 of LDASRB and no plagiarism was found in the candidate's works.

Table 1

Group	**Indicators**	**Contents**	min. points national	Points for Assoc. Prof. Angelova	min. points IICT	Points for Assoc. Prof. Angelova
A	Dissertation for the award of the educational and scientific degree "Doctor"	Defended dissertation	**50**	**50**		
B	Indicators 3 and 4	full bibliography of 10 publications referenced in WoS and/or Scopus	**100**	**240**	**100**	**240**
Г	Summe of indicators from 5 to 9	full bibliographic data of 14 publications referenced in WoS and/or Scopus and 4 publications in non-refereed peer-reviewed journals	**200**	**248.3**	**220**	**338.3**
Д	Summe of indicators from 12 to 14	87 citations in publications referenced in WoS and/or Scopus, 21 - citations in publications not referenced in WoS and/or Scopus, 2 - other	**100**	**866**	**120**	**918**
E	Summe of indicators from 16 to the end	Supervisor of a doctoral student that successfully defended PhD Thesis; Participation in 4 national and 1 international scientific or educational project; published 3 university textbooks and 2 university teaching aids	**150**	**250**	**150**	**250**

There is a declaration signed by Assoc. Prof. Angelova that the results and contributions in her scientific production are original and not borrowed.

2. General description of the submitted materials

Assoc. Prof. Angelova's publishing activity is in the areas of numerical and perturbation analyses, matrix equations, linear multidimensional control systems.

Assoc. Prof. Dr. Vera Angelova is submitted 28 publications for her participation in the competition, including 10 publications from group B4, another 18 original scientific research papers, including publications in groups Г7 and Г8, as follows:

- ✓ Thematically united and systematized scientific publications, equivalent to a monographic work with a reference to the contributions, according to Art. 29, para. 1, item 3 of the LDASRB and the Regulations on the terms and conditions for acquiring scientific degrees and holding academic positions at the BAS. The contributions cover 10 publications united in the topic area "Conditioning and Sensitivity of Matrix Equations".
- ✓ Scientific works in group Г according to indicators Г7–**14** works and and Г8–**4** works, a total of **18**, with **14** of them referenced and indexed in the world famous databases. They are in the thematic areas: "Conditioning and sensitivity of matrix equations" [Г1-Г3, Г5-Г11, Г13, Г15-Г18]' "Soft computing" - [Г4], "Personality and behavior in electronic commerce" - [Г12 , Г14].

Summaries in Bulgarian and English of all publications are presented.

The candidate participated in the competition with **3** university textbooks and **2** university teaching aids. All works are entirely within the contest's problematics. Of the publications submitted for the competition, **17** are in journals with **impact factor**, 7 are in journals with **SJR**, **2** of the publications are in journals with quartile Q1, **1** – with Q2, **3** – with Q3 and **8** – with Q4.

Assoc. Prof. Angelova's scientific works have been published in international and national journals and series with impact factor and SJR such as "Numerical Linear Algebra with Applications, John Wiley & Sons Ltd," "Mathematics, MDPI", "Lecture Notes in Computer Science", "Applied and Computational Mathematics", "Comptes Rendus de l'Academie Bulgare des Sciences"; "Studies in Computational Intelligence", as well as full-text reports at international and national forums, etc. English is used as the main language of publications. The three textbooks and the two university study aids are in French. Associate Professor Dr. Vera Angelova is presented a list certifying participation in 4 projects and contracts.

3. Reflection of the candidate's scientific publications in the scientific community (known citations)

In the reference on compliance with the minimum national requirements, Assoc. Prof. Dr. Vera Angelova has provided data on **87 citations** in scientific publications, referenced and indexed in world-renowned scientific information databases and **21 citations** in non-refereed peer-reviewed journals, etc.of her works. Citations indicate that the applicant's scientific results have gained wide popularity.

4. Overview of the content and results in the presented scientific production

The scientific output of Assoc. Prof. Dr Vera Angelova is mainly oriented in the field of studying the conditioning and sensitivity of matrix equations related to tasks from the theory of linear control systems. Pertubation analysis, as one of the main elements of numerical analysis in the theory of scientific computation, investigates the effect of modeling errors, from rounding during the computational process, etc. on the accuracy of the calculated solution. For this purpose, calculable upper bounds of the perturbation (error) in the solution of the investigated task are formulated as a function of the perturbations in the data.

Scientific publications in this area are [B1-B10, Г1-Г3, Г5-Г11, Г13, Г15-Г18].

In the articles, equivalent to a monographic work, the following were investigated and/or proposed:

- ✓ Comparative analysis of the effectiveness and reliability of most known in the literature perturbation bounds of the nonlinear matrix equation $\mathbf{X}^s \pm \mathbf{A}^*\mathbf{X}^t\mathbf{A} = \mathbf{Q}$ [B1, B2].
- ✓ The sensitivity of a solution of a nonlinear complex matrix equation $\mathbf{X}^s \pm \mathbf{A}^H\mathbf{X}^t\mathbf{A} = \mathbf{Q}$ in the general case where the exponents s and t are real numbers. A theorem for the existence of a positive definite solution of the equation is proved and local and non-local perturbation limits for it are derived. Improved expressions for the norm-wise, mixed and component-wise of this equation are derived by applying theory of norm-wise and component-wise perturbation analysis [B3, B6].
- ✓ Conditionality of the nonlinear complex matrix equation $\mathbf{X} + \mathbf{A}^H\mathbf{X}^{-1}\mathbf{A} + \mathbf{B}^H\mathbf{X}^{-1}\mathbf{B} = \mathbf{I}$ with square matrices **A** and **B**, as improved absolute and relative norm-wise, mixed and component-wise condition numbers of the equation are derived, as well as a non-local limit of the residual error in the calculated approximate Hermitian positive definite solution of the equation. Derived norm-wise nonlocal bound on the residual error in the approximate solution of the nonlinear matrix equation $\mathbf{X} - \sum_{i=1}^{m} \mathbf{A}_i^H\mathbf{X}^{-1}\mathbf{A}_i = \mathbf{Q}$ based on the method of Lyapunov majorants and the methods of the fixed point principle [B4, B5, B7].
- ✓ Obtaining low-rank approximate solutions by applying Arioldi's extended block algorithm to solving a high-dimensional, low-rank right-hand side unsymmetric Riccati differential matrix equation. An approach based on the application of the inverse differentiation formula scheme to the original problem is presented, which leads to solving algebraic Riccati equations [B8].
- ✓ An extension of two approaches of the nonlocal perturbation analysis of the symmetric differential matrix Riccati equation to the nonsymmetric case by deriving two narrow perturbation bounds that use existing sensitivity estimates of the matrix exponent and are

alternate. They allow to evaluate the accuracy of the numerical solution of the considered Riccati equation [B9].

- ✓ Comparison of three known perturbation estimates of the solution of Riccati's symmetric matrix differential equation $\mathbf{dX(t)/dt = A'X(t) + X(t)A + B - X(t)CX(t); X(0) = X_0}$; in the interval T = [0; t_1], $t_1 > 0$. Their acuity for problems with deterioration of condicionality is compared and the areas of application of the limits are indicated. The analytical solution of Riccati's scalar differential equation of one of the experimental models is proved by a theorem [B10].

Publications Г1-Г3, Г5-Г11, Г13, Г15-Г18 are related to performing perturbation analysis, sensitivity studies and/or formulation of norm-wise, mixed and component-wise condition numbers and/or derivation of local/non-local limits of residual errors of nonlinear matrix equations, incl. generalized, complex, arising in tree stochastic processes, Riccati stochastic matrix equation and others.

The scheme presented by the candidate of the scientific results contained in the publications of the competition gives detailed information in which publications the absolute and relative condition numbers, the local asymptotic and non-local nonlinear perturbation limits, the limits of the residual error in the computational solution are derived, as well as a comparative analysis of existing limits depending on the different types of matrix equations considered.

It should also be noted the significant number of applications of the solved problems: in control theory, dynamic programming, statistics, stochastic filtration, modeling of optimal interpolation problems, theory of transport processes, fluid flow models, calculus of variations, optimal evaporation and filtration, dynamic programming and differential games, nonlinear boundary value problems, stochastic linear quadratic optimization with application to investment problems in finance, and others.

Assoc. Prof. Dr. Angelova has also presented publications in the fields of soft computing [Г4] and personality and behavior in electronic commerce [Г12, Г14].

The relevance and importance of these areas is indisputable. Pertubation analysis provides an estimate of the conditionality and sensitivity of the computational task, which estimates are a mandatory element for recognizing the reliability of a numerically stable algorithm according to modern standards in engineering calculations. The investigations presented is aimed at expanding the existing knowledge in this field and has numerous applications.

Although, in addition to being independent, the candidate's works are also co-authored, I believe that her contribution to the presented works is indisputable. This is largely due to her long-standing interest in this current scientific and scientific-applied field. Moreover, Assoc. Prof. Angelova has worked and is working in a team of world-renowned scientists (Academic, Corresponding Member of BAS, Professor) in the field of mathematics and its applications, which speaks for both the high quality of the research and the high erudition of the candidate.

5. General characteristics of the applicant's activity

5.1 Scientific and organizational activity

Assoc. Prof. Angelova is Scientific Secretary of IICT - BAS since 2022. She is also a member of the Scientific Council of the Institute of Information and Communication Technologies at BAS from 2010 to 2014 and from 2022 to the present. She has been a representative of IICT in the General Assembly of the BAS since 2020. She has been a representative of the scientific direction "Information and Communication Sciences and Technologies" in the Academic Council of the Center for Training at the BAS since 2009. She is a Member of the Union of Scientists in Bulgaria and Union of Automation and Informatics. She participated in various commissions within IICT.

5.2 Teaching activity

The candidate was the scientific supervisor of 5 Ph.D. students in Scientific specialty 4.6 "Informatics and computer sciences", one of whom defended a dissertation on the topic: "Individuality and patterns in decision-making on the Internet". Since 2012, she has been a Professor in the French program of the "Faculty of Economics" of the SU "St. Kliment Ohridski" as she led lectures and exercises on the disciplines "Fundamentals of Statistics" - in French and "Applied Statistics" - in French. Prof. Angelova led the discipline: "Linear control systems" - in French for the period 1996 - 2009 in the Francophone department for electrical engineers at TU Sofia. She is a member of the state examination commissions for awarding educational qualification degrees of bachelor and master in the specialties "Economics and Finance" and "Economic Management" - Faculty of Economics of SU "St. Kliment Ohridski".

5.3 Expert activity

Assoc. Prof. Angelova is a member of the Union of Scientists in Bulgaria and the Union of Automation and Informatics. She is also a member of the editorial board of the Journal of Information Technology and Control, ISSN 1312-2622 from 2019 to the present, a member of the editorial board of Lectures Notes in Computer Science and Technologies of IICT – BAS,ISSN 2367-8666 from 2016 to date, Secretary of Cybernetics and Information Technologies journal, ISSN 1311-9702 from 2019 to date. She has prepared scientific article reviews for national and international journals as well as project reviews.

5.4 Scientific and scientific-applied activity

The projects and contracts in which Associate Professor Angelova participated are in line with the Operational Program of the Structural Funds, the Operational Program "Development of Human Resources", the European Fund for Regional Development and the National Scientific Research Fund. The international one is financed under the Framework Program of the European Commission "Scientific-Research Potential in the Convergent Areas".

6. Contributions

The scientific and scientific-applied contributions presented by the candidate for the competition are mainly in the field of studying the conditioning and sensitivity of matrix equations related to tasks from the theory of linear control systems.

I accept the summary of Assoc. Prof. Angelova's contributions in **3 scientific and 4 scientific-applied** ones, as follows:

Scientific contributions

1. Development of the Pertubation Analysis Approach Based on Fréchet Derivative Techniques for Singular Operator Matrix Problems [Г2].

The proposed development of the standard perturbation analysis technique is based on an extension to the case of a singular operator matrix based on the projection of the perturbation on subspaces of n x n positive codimension. The operator matrix of the problem is non-singular, which overcomes the drawback of the standard technique and allows obtaining the solution error equation.

2. Application of Lyapunov Majorant Techniques and Fixed Point Principles for Error Estimation at projection of the task in a Reduced-Dimensional Space [B8]

The technique of Lyapunov majorants is applied to obtain nonlocal nonlinear error bounds representing the distance between the approximate solution of the reduced-order nonsymmetric Riccati differential matrix equation and the exact solution of the full-rank unscaled nonsymmetric Riccati differential matrix equation.

3. The following mathematical expressions are proved :

   (a) Analytical solution of Riccati's symmetric differential equation [B10].

   In Theorem, the analytical solution of Riccati's symmetric differential equation is derived and

proved for the needs of the experimental analysis of pertubation limits of this equation known in the literature. The analytical solution obtained is applicable to tasks related to solving Riccati's differential equation.

(б) The Fréchet derivative of the function $A \rightarrow A^p$, with $p=1/s$ at the point A, where *s* belongs to the set of natural numbers [Г5].

In Lemma, the analytical expression of the first Fréchet derivative of the indicated function is formulated, which completes the collection of expressions of the Fréchet derivative of the function $A \rightarrow A^p$.

Scientific and applied contributions

1. New absolute and relative condition numbers, asymptotic and nonlocal upper bounds on round-off errors, and upper bounds on the residual error in solutions of matrix equations in control theory and other fields, computed in a environment of finite-machine arithmetic using numerically robust algorithm, are derived. The derived pertubation limits are not known in the literature for the considered tasks [B3-B7, B9, Г1, Г3, Г6-Г11, Г13, Г17, Г18]. The effectiveness of the proposed condition numbers and the pertubation estimates has been confirmed experimentally.
2. Known asymptotic and nonlocal perturbation bounds on solutions of matrix equations are improved. The boundaries are alternatives to pertubation boundaries existing in the literature [Г5, Г16].
3. Areas of application of existing pertubation boundaries are formulated and their properties are investigated [B1, B2, B10].

   A comparative analysis of the asymptotic and nonlocal perturbation bounds of matrix equations existing in the literature was made [B1], [B2] и [B10] and areas of their application are defined.

4. The following mathematical expression is proved:

(a) Normwise limits of the second and higher order terms of the perturbation in the matrix A of the function $A \rightarrow A^p$, for $p=1/2$ and $p=\pm r$, $r \geq 2$ [Г5].

In Lemma, normwise bounds of the terms of the second and higher order concerning the perturbation in the matrix A of the mentioned function for $p=1/2$ and $p=\pm r$, p is natural number and $r \geq 2$ are derived. The derived normwise limits have an independent meaning in the study of the function.

7. Personal impressions and opinion of the reviewer

I have known Assoc. Prof. Dr. Vera Angelova since 1994. Although we work in different institutes, my personal impressions are entirely positive. She is always positive and collegial, I am impressed by her activity over the years and development in many areas. In addition to being a thorough and qualified scientist, she also stands out as an excellent organizer in her activities as Scientific Secretary of IICT-BAS and representative of the scientific direction "Information and Communication Sciences and Technologies" in the Academic Council of the Training Center at BAS. Her teaching activity is also at a high level.

After my detailed acquaintance with the scientific production of the candidate, I consider that her participation in the current competition for a professorship is proof of the positive development of her potential as a researcher.

Assoc. Prof. Angelova's scientific contributions are substantiated and correspond to the actual results achieved. The candidate has serious scientific publications on the issues of the competition, approved in authoritative domestic and international publications and international scientific forums. The presented production, results and achievements confirm Associate Professor Vera Angelova as a highly erudite and respected scientist.

8. Critical notes and recommendations

I don't have any critical remarks about Assoc. Prof. Angelova. I recommend that she summarize and present her results in a monographic paper.

9. Conclusion

Bearing in mind the above, I consider that Assoc. Prof. Dr. Angelova fully meets the conditions, criteria and requirements for the selection of the academic position of "Professor" according to the Law on the Development of the Academic Staff of the Republic of Bulgaria, the Regulations for the application of the Law on the Development of the Academic Staff of the Republic of Bulgaria, the Regulations on the terms and conditions for acquiring scientific degrees and holding academic positions at the Bulgarian Academy of Science and the specific requirements for holding the academic position "Professor" at IICT-BAS. Based on this, I give my positive vote and propose to the members of the esteemed Scientific Jury to elect **Associate Professor Vera Angelova Angelova-Dimitrova** for the academic position **"PROFESSOR"** in the field of higher education 5.2. Electrical engineering, Electronics and Automation, scientific specialty "Application of the principles and methods of cybernetics in various fields of science (technical), for the needs of the section "Intelligent Systems" and propose to the respected Scientific Council of IICT-BAS to confirm the selection.

На основание
ЗЗЛД

27.02.2024

Sofia / Prof. D