REVIEW

in relation to the competition for the academic position of Professor in the field of higher education 4. "Natural Sciences, Mathematics and Informatics", professional field 4.5. Mathematics, specialty "Mathematical Modelling and Application of Mathematics in 3D Digitalization and Microstructural Analysis", announced in State Gazette No. 103 of 12.12.2023 for the needs of the National Scientific Research Institute "Scientific Computing with Laboratory of 3D Digitization and Microstructural Analysis", Institute of Information and Communication Technologies, Bulgarian Academy of Sciences.

Reviewer: Rumen Zlatev Iankov, Professor, Institute of Mechanics - BAS. Approved as a member of the scientific jury in the competition for professor, announced in State Gazette No. 103 of 12.12.2023 by Order No. 40 of 09.02.2024 of the Director of the Institute of Information and Communication Technologies (IICT-BAS), Bulgarian Academy of Sciences.

For participation in the competition for the academic position "Professor" announced in Official Gazette No. 103 of 12.12.2023 and on the website of IICT-BAS, documents were submitted by Assoc. Prof. Dr. Ivan Georgiev Georgiev.

I have been provided with the following documents:

1. curriculum vitae according to European standard;
2. a copy of the diploma for the educational and scientific degree "Doctor";
3. certificate of experience in the specialty;
4. a list of the scientific publications submitted for the competition, which do not repeat those submitted for the PhD degree or of Doctor of Science (if any degree) and for the academic position of Associate Professor;
5. a list of citations;
6. abstracts of the scientific publications for the competition - in Bulgarian and English;
7. copies of the scientific publications for the competition;
8. a filled form on the fulfilment of the minimum requirements of the IICT-BAS;
9. statement of original scientific and applied contributions;
10. a declaration that there is no plagiarism in the scientific works proven under the statutory procedure;
11. an electronic medium with information as required by the IICT-BAS.

1. Biographical data:

Assoc. Ivan Georgiev is a graduate of Sofia University "St. Kliment Ohridski," where he obtained his doctoral degree in Computational Mathematics in 2007. He has held various positions since 2003, starting as a mathematician at IMI-BAS, progressing to the role of senior assistant at IMI-BAS, and currently serving as an associate professor at IIT-BAS. Notably, since 2021, he has assumed the role of Scientific Secretary of BAS for the field of Information and Communication Sciences and Technologies.

2. General characteristics of the scientific results

The Scopus database shows that the refereed works of Assoc. Prof. Ivan Georgiev in this database are 63 (45 of them were published in the period 2015-2024), with 149 independent

citations registered so far for the whole period (the Hirsch index of the candidate is 7, excluding self-citations of all co-authors).

Assoc. Prof. Ivan Georgiev has submitted 21 scientific publications for consideration in the competition for the academic position of "Professor." Among these publications, 15 appear in journals indexed in SJR, comprising 2 in scientific journals and the remainder in conference proceedings (including 4 in LNCS, 2 in AIP CP, 5 in Studies in Computational Intelligence, 1 in MATEC WoC, and 1 in SGEM). Additionally, 3 publications are in journals with impact factors distributed across Q1, Q2, and Q4 categories, and 2 other publications are included. Notably, all publications are in issues dated after 2015, following Ivan Georgiev's appointment as Associate Professor, and were not utilized in previous evaluation procedures.

The candidate's materials for the current competition include data on 57 citations of his scientific publications, with 47 stemming from articles submitted for consideration in this competition. These citations are sourced from publications reviewed in Web of Science and Scopus, indicative of the favorable recognition of the scientific contributions made by Assoc. Prof. Ivan Georgiev.

The research subjects addressed in the publications under consideration pertain to scientific problems within the professional field of 4.5 Mathematics, specifically focusing on mathematical modelling and the application of mathematics in 3D digitization and microstructural analysis.

Fulfilment of the minimum requirements for the academic position of "Professor" according to the Regulations for Academic Positions in the Institute of Information and Communication Technologies.

The requirements for the individual groups of criteria for the academic position of "Professor" in the professional field 4.5. Mathematics are higher than those in the Regulations for the Application of the Law on Mathematics. The analysis below is made according to these increased requirements.

Group A: A copy of the diploma issued by the HAC to the Council of Ministers with No. 31417 dated 23.05.2007 for the degree of PhD in the scientific specialty 01.01.09 "Computational Mathematics" - 50 points.

Group C: For habilitation work - scientific publications in journals that are refereed and indexed in world-known databases of scientific information, 5 articles in conference proceedings that have SJR and one article in journal with SJR (for 2022 this journal has also an IF). These publications are related to microstructural analysis and numerical homogenization based on micro-tomographic images with application to porous and composite materials - *120* pts (minimum 100 pts).

Group D: In the reference prepared by the candidate, a total of 12 publications in journals are given for indicator 7 as follows: 3 with IF (Q1, Q2, Q4), 9 with SJR - *294* pts (minimum 260 pts).

Group E: 57 independent citations of the candidate's publications are provided, the citations are discoverable in Web of Science and Scopus - *342* pts (minimum 140).

Group F: For indicator 14 - participation in 5 national projects (50 pts.), for indicator 15 - participation in 3 international projects (60 pts.), for indicator 16 - leader of 2 national projects (40 pts.), for indicator 17 - leader of 1 ongoing international project (50 pts.) - *200* pts. (minimum 150 pts.)

The conclusion is that Assoc. Prof. Georgiev meets, and in some indicators exceeds the minimum requirements for the academic position of "Professor" at IICT-BAS.

3. **Contributions in the field of the competition according to the works submitted for review.**

The results obtained and the scientific interests of the candidate are in the field of development and application of effective methods and approaches for interdisciplinary research using state-of-the-art tools for 3D digitalization, visualization, prototyping and numerical simulations based on 3D digital reconstructions of the microstructure of the objects under study.
The candidate's results can be structured in the following main areas:

- Development of numerical models based on cutting-edge methods, algorithms and software tools for voxel and polygonal data processing.

- Application of computed tomography in numerical homogenization for material characterization of porous materials.

- Applications of mathematics in the use of advanced digitization tools in industry, medicine and for the digital reconstruction of three-dimensional objects.

In the **first** research area, different methods for image segmentation obtained by industrial X-ray computed tomography of porous materials have been investigated (2, 9, 10 and 22). Two-phase segmentation of a 3D grey-scale image is considered under the constraint that the number of voxels within the phases is fixed a priori. Two parallel algorithms based on a 2-Laplacian graph model are proposed, implemented and tested numerically.

In (9), the use of an iterative algorithm of the fastest descent type is proposed, for which convergence to the exact solution of the discrete optimization problem associated with image segmentation using graph-Laplacian is observed. Such an algorithm in combination with an innovative processing of the specimen surface allows for significant additional improvements in segmentation quality, in contrast to the standard strategy of simple thresholding. The proposed algorithm has been verified in various numerical experiments that prove its practical value.

In (22), a novel method for segmentation of grayscale images is introduced, utilizing the extraction of multiple features from individual image pixels. This approach incorporates the intensity value of each pixel and employs a recurrent neural network, specifically an Echo State Network from the reservoir computing family. The method is implemented in addressing a real-world challenge of segmentation of bone's 3D tomographic images, aiming to elucidate the object's internal structure. The results demonstrate that the proposed approach enhances the clarity of internal bone structure details. Validation of the method supports its efficacy in analysing tomographic images of various materials.

The second research direction is related to research based on various methods for determining effective material characteristics of porous and composite materials by applying microstructural analysis and high-performance computing tools (3,4,7,8).

Some of the studies are related to the numerical homogenization of anisotropic linear-elastic materials with highly heterogeneous microstructure (3). An algorithm has been developed and applied to the case of a two-phase composite material: an epoxy resin-based nanocomposite with a filler of clay nanoparticles. The upscaling procedure is described in terms of six auxiliary elastic problems for the reference volume element. A parallel PCG method is applied to efficiently solve the large systems of equations with sparse, symmetric and positive semi-

definite matrices arising from the application of the numerical procedure. The bulk modulus tensor is calculated from the stiffness tensor, and its eigenvectors are used to determine the transformation matrix. The material stiffness tensor is transformed with respect to the principal directions of anisotropy, which gives a canonical (unique) representation of the material properties. The numerical homogenization result is a mathematical model that adequately reflects the microstructure of the two-phase composite material. However, this approach leads to large sized systems of equations requiring the use of significant computational resources.

In (7), a problem related to a multiscale material modelling approach is also considered. The mechanical behaviour of fibre reinforced concrete is modelled. To determine the stiffness, an odd homogenization is applied. By solving the inverse problem, the local material characteristics are determined. This approach requires repeated solution of large finite element boundary value problems with up to 200 million degrees of freedom. This also determines the use of computational resources with significant capacity and the conduct of high-performance computing (HPC).

The studies in (8) are devoted to a 3D hybrid numerical-experimental homogenization strategy for determining the elastic characteristics of closed-cavity materials (porous materials). The applied homogenization procedure uses micro-computed tomography (micro-CT) and instrumented indentation testing (IIT) data. Based on the micro-CT data, a 3D geometric model of a cubic representative volume element (RVE) is created. A periodic microstructure (periodic repetition of the RVE) is assumed and the shape of the pores is assumed to be spherical in order to simplify the model. The following equivalence principle is followed in the creation of the finite-element model of the RVE: the porosity is calculated based on the micro-CT images, and the voids have a spherical shape with the sphere size distribution taken from the micro-tomography data. The numerical homogenization technique involves appropriate periodic boundary conditions with a single force applied in the normal and shear directions. The constitutive model used for the solid phase is the linear elastic model whose parameters were determined using IIT data. A validation and verification study was performed using simplified geometries for RVE and under different assumptions to model the cavity size distribution.

The third scientific direction is related to the applications of mathematics in the use of advanced digitization tools in industry, medicine and the reconstruction of three-dimensional objects.

In (14 and 16) applications of three-dimensional digitization methods and tools (3D laser scanning and industrial X-ray computed tomography) in the examination and characterization of bone specimens are presented.

In (13), a simulation of the blood flow process in blood vessels using real vessel geometry data obtained by computed tomography is presented. Numerical results on geometries extracted from patient angiographic data were obtained using the specialized MEDVIS 3D software and in close collaboration with the Medical Informatics Group at Johannes Kepler University in Linz, Austria.

In (11 and 12), mathematical and computer modelling tools are used to describe the fluid transport processes in porous media and the removal of various contaminants in artificial wetlands. A computer model based on the solution of inverse problems was created by which the corresponding linear and nonlinear absorption models were built to simulate the removal of phosphorus from horizontal subsurface wetlands. The Visual MODFLOW computer code was verified for computer simulations and experiments. Experimental data from horizontal subsurface wetlands that were actively monitored for two years in Xanthi, Greece were used in

the corresponding mathematical and computer models and to compare the results of the computer simulations and field experiments. In (18 and 19), the cases where some of the input parameters are not known exactly and their values are given in some interval are investigated. Such kind of uncertainty of input parameters is treated by a stochastic numerical approach based on Monte Carlo methodology.

In (15), a detailed analysis of the feasibility of creating lightweight broadband polymer antenna prototypes by 3D printing and metallization is presented. For this purpose, a prototype of a standard metallic pyramidal antenna is compared with its 3D printed twin. Three different 3D polymer printers were tested. The printed specimens were evaluated non-destructively by industrial X-ray computed tomography, then metallized by chemical and electrochemical deposition. To evaluate the quality of metallization, micro-computed tomography, X-ray fluorescence analysis and nanoindentation were used. This resulted in a quality polymer prototype ten times lighter than the original. This is the first known comprehensive analysis of the feasibility of 3D printing lightweight broadband polymer antenna prototypes with stable chemical metallization and radio properties close to those of the original.

4. General description of the applicant's professional activities

4.1. Teaching and pedagogical activity

Assoc. Georgiev has so far mainly worked with students as follows:

- SU-FMI, Numerical Methods Part 1, guided exercises
- Supervisor of two graduate students at SU-FMI (Iliana Vladeva - defended 2017 and Silvi-Maria Gyurova - defended 2018).
- Supervisor of 3 graduate students in the student practice program (Ventsislav Pirinski - TU Sofia, Isabel Popova and Georgi Vassilev - AMTII Plovdiv)

4.2 Scientific, applied, project and editorial contributions

The scientific activity of the candidate is largely reflected in the publication activity, which I assess as very good. In addition, Assoc. Prof. I. Georgiev has been the head of 3 scientific projects funded by the National Research Fund and one of them was the head of the team of the partner organization - IICT; he is a member of the Board of the national interdisciplinary research E-infrastructure CLADA-BG. Within the Centre for Computer Science and Information and Communication Technologies, he is the head of the Laboratory for 3D Digitization and Microstructural Analysis, whose establishment and functioning Assoc. Prof. Georgiev has the decisive role in the establishment of the Laboratory. He has been involved in 4 international research projects and is currently the team leader of the ICT team that is part of the recently launched HORIZON WIDERA 2022 ACCESS 04 BCThubs: Blue Culture Technology Excellence Hubs in EU Widening Member States project. Guest editor of 7 volumes of Springer series and 1 issue of Elsevier journal. He has been the Chair of the SIAM Section on Biomathematics and Scientific Computing since 2016, and served one term as the Chair of the SIAM Bulgarian Section.

5. Evaluation of the personal contribution of the candidate

Assoc. Prof. Ivan Georgiev has presented a detailed author's report on the scientific and applied contributions reflected in his scientific publications. I fully accept the formulations and accents in the author's reference.

I accept that the candidate's contribution to joint scientific publications is equivalent to the contributions of all co-authors, where applicable. No data on the distribution of the co-authors' contributions are presented.

6. **Critical remarks**

In future scholarly activity, the applicant should emphasize publication of results in prestigious indexed and refereed scholarly journals and pay attention to training of doctoral students and supervision of postdoctoral fellows.

7. **Personal impressions**

I have direct impressions of the candidate from collaborative work on scientific and applied projects. His ability to communicate clearly and stimulate innovative thinking makes any collaboration with him stimulating and productive. My impression is that Assoc. Prof. Dr. Ivan Georgiev distinguishes himself as a visionary and as a highly effective leader of the 3D Laboratory for Digitization and Microstructural Analysis. His ability to engage young scientists in the Lab with interesting and contemporary issues is impressive. He not only provides valuable guidance and leadership, but also inspires them to develop their skills and learn new ones. Assoc. Prof. Georgiev possesses very good organizational qualities pro teamwork, which I have the impression of his participation in the preparation and conduct of scientific forums and other forums aimed at the presentation and dissemination of scientific and applied results, in addition to actively supporting the activities of the SMB and the Bulgarian section of SIAM.

8. **Conclusion:**

The candidate for the announced competition, Associate Professor Ivan Georgiev Georgiev, PhD, fully meets the requirements of the ZRASRB, the Regulations for the Implementation of the ZRASRB, the Regulations for the Terms and Procedures for Acquiring Scientific Degrees and Borrowing Academic Skills at the BAS, as well as the Regulations for the specific conditions for acquiring scientific degrees and taking up academic specialties at the Institute of Information and Communication Technologies at the BAS.

Taking into account the above and the scientific and applied results of the candidate, **I strongly recommend to the esteemed scientific jury of the competition to propose to the Scientific Council of IICT-BAS to elect Assoc. Prof. Dr. Ivan Georgiev Georgiev to occupy the academic position "Professor"** at IICT-BAS in the field of higher education 4. "Natural Sciences, Mathematics and Informatics", professional field 4.5. "Mathematics", specialty "Mathematical Modelling and Application of Mathematics in 3D Digitization and Microstructural Analysis", for the needs of the Department Scientific Computing with Laboratory for 3D Digitization and Microstructural Analysis, Institute of Information and Communication Technologies at the Bulgarian Academy of Sciences.

5.04.2024 г. Member of the Scientific

/Prof. Rou

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