REVIEW

by Corresponding Member of BAS, DSc. Svetozar Dimitrov Margenov,
Professor at IICT-BAS,

of materials submitted for participation in a competition
for holding the academic position "Professor" at IICT-BAS
in professional field 4.5 Mathematics, scientific specialty
"Mathematical Modeling and Application of Mathematics in 3D Digitization and Microstructure Analysis"

In accordance with Order № 40/09.02.2024 of the Director of IICT-BAS and decision of the appointed scientific jury, I am elected as a reviewer under the competition for professor, published in the State Gazette (issue 103/12.12.2023). Documents for participation in the competition were submitted by Dr. Ivan Georgiev Georgiev, Associate Professor in the Department of Scientific Computations with Laboratory for 3D Digitization and Microstructure Analysis at IICT-BAS.

1. Brief biographical data

Assoc. Prof. Dr. Ivan Georgiev graduated in 1999 from the Faculty of Mathematics and Informatics at Sofia University "St. Kliment Ohridski" with a Master's degree in Mathematics. In the period 2000 - 2002, he was a graduate student at the Institute for Parallel Processing (IPP) at the Bulgarian Academy of Sciences, where in 2007 he defended a dissertation to obtain the educational and scientific degree "Doctor" in "Computational Mathematics".

From 2007 to 2014, he was a senior assistant professor at IMI-BAS. In the period 2008 - 2013, he was on specializations for 38 months at the Johann Radon Institute for Computational and Applied Mathematics of the Austrian Academy of Sciences in Linz. In 2015, he was elected as an associate professor at IICT-BAS in the scientific specialty "Computational Mathematics (Scientific Computations)". Since 2018, he has been leading the Laboratory for 3D Digitization and Microstructure Analysis built at the institute within the Center of Excellence in Informatics and ICT. Since 2221, he has been a scientific secretary of BAS.

Assoc. Prof. Georgiev has been the chairman of the "BioMathematics and Scientific Computations (BMSC)" section of the UBM since 2016. In the period 2015-2022, he was in the leadership of the Bulgarian section of SIAM (BGSIAM), of which since 2019 until 2022 he was the chairman.

2. General description of the presented materials

The materials presented by Assoc. Prof. Ivan Georgiev Georgiev are prepared in accordance with the Development of Academic Staff in the Republic of Bulgaria Act (DASRBA), the Regulations for the Application of DASRBA (RDASRBA), as well as with the specific requirements of the Regulations of BAS and IICT - BAS. They include: application for admission to the competition; curriculum vitae according to the European model; copy of Diploma for the educational and scientific degree "Doctor" (PhD); official note for internship in the specialty; list of scientific publications for participation in the competition; list of noticed citations; abstracts of the scientific publications with which he participates in the competition – in Bulgarian and English; copies of the scientific publications with which he participates in the competition; reference for the fulfillment of the minimum national requirements under Art. 2b, para. 2 and 3 and the requirements of IICT under Art. 2b, para. 5; reference for the original scientific and scientific-applied contributions; declaration that there is no legally proven plagiarism in scientific works.

For participation in the competition Assoc. Prof. Ivan Georgiev presented 21 scientific publications (numbered from 2 to 22) covering the period 2015 - 2024 (including 7 published in the last 5 years). All publications are in English. There are 3 papers in specialized scientific journals with impact factor (IF) (1 of which is in quartile Q1, 1 in Q2 and 1 in Q3). Of the other papers, 16 are in specialized series with SJR. Of the publications presented for participation in the competition, 4 are with 2 co-authors, 5 - with 3, 6 - with 4 and 6 - with more than 4 co-authors.

The report on the implementation of the minimum national requirements and the requirements of IICT-BAS for the academic position "Professor" contains in a table form data by groups of indicators. The points on each of the indicators exceed the required ones, as follows: G - 302 against the required 260; D – 342 against the required 140; E – 200 against the required 150.

3. General characteristics of the candidate's activity

Assoc. Prof. Ivan Georgiev is an established scientist in the field of mathematical modeling and the application of mathematics, and also has made significant contributions to computational mathematics. The research methodology in the results presented for participation in the competition includes: 3D digitization, visualization and prototyping; processing of voxel and polygonal data, including image segmentation; microstructure analysis of composite and porous materials; numerical homogenization to determine effective macro-characteristics.

In the materials submitted for participation in the competition, it is documented that Assoc. Prof. Georgiev led 3 scientific and scientific-applied projects: two of them were financed by the National Science Fund and one by the EC HORIZON-WIDERA

program. Additionally, he participated in 8 projects with international (including under EC framework programs) or national funding.

The candidate has actively participated in the organization of international scientific conferences, as chairman or member of organizing and program committees. I will note in particular that Assoc. Prof. Ivan Georgiev was the editor of 7 volumes of Springer series and 1 special issue of an Elsevier journal.

4. Scientific and applied scientific contributions

The presented scientific and scientific-applied contributions of Assoc. Prof. Ivan Georgiev are in accordance with the scientific specialty "Mathematical Modeling and Application of Mathematics in 3D Digitization and Microstructure Analysis".

In the review, I adopt the following thematic classification of the presented results:

I. Methods and algorithms for numerical homogenization and determination of effective macro-characteristics of materials [3-8];
II. Segmentation of images obtained by X-ray computed tomography of porous and composite materials [2,9,10,22];
III. Methods and algorithms for reconstruction and characterization of objects with a complex three-dimensional structure [14,16,17,20,21];
IV. Biomedical and engineering applications of mathematical modeling using 3D digitization and microstructure analysis [11-13,15,18,19].

Publications [2-8] are included in Group B of the reference for fulfillment of the minimum requirements, as equivalent to habilitation thesis. This cycle of works is well defined thematically and has a clearly determined complete character. Mathematical models, numerical methods and algorithms are included here, as well as a comparative analysis of results from numerical experiments and laboratory tests.

The number of publications in which results by individual groups are presented is 6, 4, 5 and 6, respectively.

I. Methods and algorithms for numerical homogenization and determination of effective macro-characteristics of materials.

Numerical homogenization is a mathematical method for determining the parameters of materials with a complex internal structure. In the results presented in this group, information about the microstructure is used to compute the macrocharacteristics. Such information is extracted using industrial computed tomography. After segmentation of the tomographic image, the required voxel representation of the three-dimensional object is obtained. In numerical homogenization, to determine the characteristics of the material at the macro level, boundary problems at the micro level are solved in the so-called reference volume element. Their number is equal to the number of searched parameters. For example, 6 such problems are solved to determine the moduli of elastic deformation and volume deformation coefficients of anisotropic materials. Specialized methods and algorithms for discretization (for

example, finite element method) and methods for solving systems of linear algebraic equations with sparse matrices are used for the numerical solution of problems in the reference volume element. The computational complexity of numerical homogenization depends on the microstructure of the meda. So for example: in [3,6] the composite material consists of highly heterogeneous components; in [5], the concrete is reinforced with fibers, which leads to a large geometric heterogeneity; in [8] the media is characterized by internal cavities, In these studies, methods and algorithms for solving very large systems of linear algebraic equations are integrated. In them, the number of unknowns reaches the order of $O(10^9)$. The condition number of the corresponding sparse matrices is even larger. Papers [3,4,5,7] analyzed the parallel speed-up and efficiency of the developed algorithms on some of the most modern supercomputer architectures.

II. Segmentation of images obtained by X-ray computed tomography of porous and composite materials.

Results related to segmentation are mainly published in works [2,9,10,22]. It is important to note that when scanning 3D microstructures, the images are of a very large voxel dimension. The goal is to obtain maximum accuracy within the resolution capacity of the X-ray tomograph being used. Specific difficulties in industrial computed tomography are related to the high density of the investigated materials. Image segmentation is an important step in building a quality digital model. A good delineation of interface boundaries leads to complex optimization problems. To ensure the adequacy and reliability of the numerical model, specific quantitative constraints are imposed on appropriately defined functional spaces in which the solution is sought. There are cases in which phase connectivity requirements are also imposed. In [2], two-phase segmentation of a 3D image with a fixed number of voxels in the phases is considered. Two parallel algorithms are proposed, based on a model reducing the problem to linear systems with sparse graph-Laplacian matrices. This class of systems is also considered in [10], where the convergence rate of the steepest descent iterative method was experimentally investigated. A qualitatively new approach is proposed in article [22]. Using a recurrent neural network, multiple features characterizing the microstructure were extracted based on the voxel values of the image. A problem of another type is considered in [9]. Using surface treatment (coating with a contrast layer) of an open-pore specimen, a segmented tomographic image with improved quality was obtained.

III. Methods and algorithms for reconstruction and characterization of objects with a complex three-dimensional structure.

Papers [14,16,17,20,21] are the result of the candidate's joint work in interdisciplinary teams on innovative and current topics. The problem of 3D reconstruction of a homogeneous media with high-density inclusions is considered in [17]. A specialized method and algorithm have been developed. The approach is based on the correction of radiographic projections by replacing the data for the high-density areas

by synthesized data obtained using 2D interpolation. Papers [20,21] are in the field of materials science. The subject of research is materials used for the synthesis of: a) glass, including metallurgical slag; b) glass ceramics with an attractive appearance, including fly ash, blast furnace slag and zinc and copper production waste. Using 3D industrial computed tomography, the distribution of residual porosity was analyzed, and pore size and shape were characterized. Another class of applications is discussed in [14,16]. They present and analyze linear features of anthropological objects obtained using 3D digital models created by laser scanning. For example, in [16] cranial material from the latest Middle Pleistocene deposits was studied, and a new classification analysis of the so-called "small cave bears" was made.

IV. Biomedical and engineering applications of mathematical modeling using 3D digitization and microstructure analysis

To this group are regarded publications [11-13,15,18,19]. They reflect another direction important for the candidate's scientific interests. Determining for these articles are the complex nature of the research and the results obtained. In particular, I will focus on 2 of these 6 papers. In [13], a mathematical model of a brain aneurysm is presented, including dynamics of blood flow in interaction with the walls of the blood vessel. The goal is to assess the risk of rupture based on blood pressure distribution, flow velocity, and wall stresses. The geometry of the computational domain is derived from high-resolution medical images of the patient. The blood is modeled as an incompressible Newtonian fluid, and the vessel walls as an isotropic linear elastic material. The discretization is by the finite element method. To solve the resulting systems of linear algebraic equations, an iterative conjugate gradient method with an algebraic multigrid preconditioner is applied. The algorithm has optimal computational complexity. The second of the selected papers is related to an engineering application. In [15], a new approach for manufacturing radio antennas by 3D printing and chemical metallization is proposed. A non-destructive inspection of the printed forms is carried out using industrial X-ray computed tomography, after which they are metallized by chemical and electrochemical deposition. Conducted high-tech radio measurements have shown full compatibility with the significantly more expensive and heavier metal original. As the applicant notes, this is the first known comprehensive analysis of the feasibility of 3D printing lightweight broadband polymer antennas with stable chemical metallization for frequencies in the 14 - 18 GHz range. In conclusion,

I will once again note the complex nature and scope of the presented scientific and scientific-applied results of Assoc. Prof. Ivan Georgiev, a significant part of which are of a pronounced interdisciplinary nature.

5. Impact of the applicant's scientific publications

The candidate has provided a list of 57 citations in publications that are referred and indexed in the scientific information databases WoS and Scopus. Of these, only 4 are

citations to non-journal papers. In accordance with the requirements, the citations are formed in a table with data in the group of indicators E. With a minimum required of 140 points, the presented assessment of citations is 342 points. With the exception of one, all the citations included in the table are in the works of foreign authors, including those published in the most authoritative specialized international journals and series. For example, for the paper [13] (Kyovtorov, V., Georgiev, I., Margenov, S., Stoychev, D., Oliveri, F., Tarchi, D.: New antenna design approach – 3D polymer printing and metallization. experimental test at 14–18 GHz. AEU - International Journal of Electronics and Communications, 73, Elsevier, 2017, 119-128) 24 citations are shown, most of which are in journals with an impact factor (IF). I will note that according to Google Scholar, the citations for this article are 40, with no self-citations among them.

6. Evaluation of the applicant's personal contribution

I accept that in the joint papers, Assoc. Prof. Ivan Georgiev has an equal role, as I am convinced of his leading role in the development of specialized numerical methods and algorithms and their integration and interpretation in the interdisciplinary context of the presented mathematical models.

7. Critical remarks

I don't have any essential critical remarks about the materials of Assoc. Prof. Ivan Georgiev, presented within the present procedure.

I would recommend that in the future more results be submitted for publication in authoritative, highly ranked journals. I believe that not a small part of the articles submitted to the competition published in conference proceedings, have the qualities to be accepted in such journals after appropriate refinement.

8. Personal impressions

I have known Ivan Lirkov since 1999. Our joint work begins within the framework of his postgraduate studies (doctoral studies). I have very good memories of that period. Publications included in the dissertation continue to attract interest. In the following years, we continue to work successfully on a number of joint projects.

I highly value the professional growth of Assoc. Prof. Geortiev. He is a built scientist with proven capabilities for in-depth research and analysis, as well as for working on innovative tasks in interdisciplinary teams.

9. Conclusion

After getting acquainted with the materials of the competition, the complex evaluation of the applicant's qualities, including the scientific and scientific applied contributions, **I strongly recommend Assoc. Prof. Dr. Ivan Georgiev Georgiev to be elected to the academic position of "Professor"** at IICT – BAS in professional field 4.5 Mathematics, scientific specialty "Mathematical Modeling and Application of Mathematics in 3D Digitization and Microstructure Analysis ".

На основание
ЗЗЛД

03.04.2024
Sofia

Reviewer:
/ Prof. Svetc
Correspondi