

# STATEMENT

on dissertation work for obtaining  
scientific degree "**Doctor of Sciences**"

Author of the dissertation: **Assoc. Prof. Dr. Eng. Galya Nikolova Georgieva-Tsaneva**

Title of the dissertation: **Hybrid approaches to building a digital twin of heart rate variability**

Field of higher education: **5. Technical sciences**

Professional field: **5.2 Electrical engineering, electronics and automation**

Scientific specialty: **Elements and devices of automation and computing**

Member of the scientific jury: **Prof. DSc Eng. Iliana Yordanova Marinova**

## 1. Relevance of the problem developed in the dissertation in scientific and applied terms

The research in the dissertation is in the field of processing, analysis and modeling of cardiological signals, using information and communication technologies to build a digital twin of heart rate variability.

The rapidly emerging digital transformation of healthcare in accordance with the development of telemedicine, artificial intelligence, large databases, virtual engineering and electronization places qualitatively new requirements on modern healthcare platforms for continuous monitoring of the patient's physiological conditions in real time.

The new engineering challenges in terms of building digital twins make the research and the results obtained in the dissertation relevant and significant in scientific and applied aspects.

The purpose of the dissertation is the development and study of an integrated hybrid methodological framework for processing, analysis, modeling and protection of cardiological signals, based on a combination of classical mathematical and modern AI-based approaches, supporting the construction of a digital twin of heart rate variability in IoT environments. To achieve this goal, seven tasks have been formulated.

## 2. Degree of knowledge of the state of the problem.

The presented dissertation is presented on 245 pages, including an introduction, five chapters, a conclusion, main contributions, a list of publications on the dissertation, and cited literature. The list of literature used is composed of 235 literary sources in Latin. In the first chapter of the dissertation, a review and analysis of the methods for processing, analysis and security of cardiological data is made. On this basis, conclusions are drawn about the need for an integrated, hybrid and methodological framework for processing, analysis, simulation and protection of cardiological signals. The dissertation candidate has demonstrated good knowledge of the state of the problem and, based on the analysis of its known literature, the goal and objectives of the dissertation are formulated.

## 3. Scientific and scientific-scientific contributions of the dissertation

The author has summarized the obtained results in the dissertation work and presented them as 4 scientific, 3 scientific-applied and 2 applied contributions, which can be presented as

### Scientific contributions:

- A concept for a digital twin of heart rate variability has been formulated as a customizable and dynamic framework for modeling, interpretation and prediction of autonomic cardiac regulation;

- Original methods for analysis and detection of Photoplethysmographic/ Electrocardiographic signals have been proposed;
- New simulation models for heart rate variability, photoplethysmographic and electrocardiographic signals have been developed;
- A regionally adaptive principle for cardiological data protection has been formulated.

Scientific and applied contributions:

- Methods for adaptive noise suppression, reliable detection and extraction of intervals from photoplethysmography and electrocardiography have been developed;
- Three integral indices have been created - for fatigue assessment, short-term recovery and long-term adaptation, tested on data from athletes under different training regimes;
- Methods and architectures for secure processing of cardiological data have been developed, including hybrid cryptography, watermarking and mechanisms for traceability and authenticity, as well as a multi-index method for automatic signaling of physiological risk in real time.

Applied contributions:

- The applicability of photoplethysmography-based interval series as a practical alternative to electrocardiography in remote monitoring and portable systems is argued;
- The potential of the developed methods for application in telemedicine, sports science, personalized monitoring and IoT-based systems is demonstrated, and an architectural basis for future development of the concept of a digital twin of heart rate variability is outlined.

I accept the formulated contributions from the author and I convincingly consider that the scientific and scientific-applied contributions of Assoc. Prof. Tsaneva's dissertation are relevant and significant for science with applications in healthcare and personalized medicine.

#### **4. Publications on the dissertation**

The dissertation is presented with 25 publications that fully reflect the work on the dissertation. There are 14 publications with IF or SJR, 10 publications are presented at conferences and 1 chapter of a monograph. Seven publications are with only author Assoc. Prof. Tsaneva. This clearly shows the personal and leading contribution of Assoc. Prof. Tsaneva.

The publications on the dissertation in quantitative and qualitative terms significantly exceed the requirements of the normative documents and with a total of 350 points required for indicators A, Б, Г and Д, the candidate has achieved 1132.64 points. The presence of 71 citations of publications on the dissertation, 52 of which in the Scopus database, is an indicator of the quality of the publications made. The main results of the dissertation are sufficiently well-presented to the international scientific community.

#### **5. Opinions, recommendations and notes.**

The dissertation work is in a field that is actual, interdisciplinary and difficult. The research was done qualitatively and the presented dissertation has scientific, scientific-applied and applied contributions. I have no serious critical remarks, but the large number of abbreviations significantly complicates the perception of the material, especially in the dissertation digest. A number of terms are used in both Bulgarian and English, such as digital twin, etc., the figures are captioned in English, and it would be good to translate them into Bulgarian. Some results are difficult to evaluate, since there is a discrepancy in the time intervals before and after processing, e.g. Fig. 2.15 and Fig. 2.16. The software implementation of the developed algorithms, e.g. for noise reduction, etc., is not commented on. Not enough information is presented about the data sources used in some experiments, as well as about the reproducibility of the experiments performed. My recommendation is the

author of the dissertation to continue to work in this area for the practical implementation of the results obtained in the dissertation.

## **6. Conclusion**

Based on the presented dissertation work and the publications made, the achieved results, the scientific, scientific-applied and applied contributions contained therein, I consider that the dissertation work meets the requirements of the Law for the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its implementation, the Regulations on the conditions and procedure for acquiring scientific degrees and for occupying academic positions at the Bulgarian Academy of Sciences and the rules for the development of the academic staff of the Institute of Robotics-BAS. I give a positive assessment of the dissertation work and suggest

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be awarded the scientific degree "DOCTOR OF SCIENCES" in the scientific specialty "Elements and devices of automation and computing" in Professional field 5.2 Electrical engineering, electronics and automation, Field of higher education 5. Technical sciences.

8.06.2026

JURY MEMBER:

/Prof. D.Sc. Iliana Marinova/