OPINION

of the dissertation for the award of scientific and educational degree "Doctor" in the field of higher education - 5. Technical sciences, in the professional field - 5.2. Electrical engineering, electronics and automation, scientific specialty - 02.21.01 "Elements and Devices of Automation and Computer Engineering"

Author: eng. Krassimir Yordanov Cheshmedzhiev

Dissertation topic: "Portable computer system for cardiac signals"

Member of the scientific jury: Assoc. Prof. Eng. Prodan Ivanov Prodanov, PhD

1. Topic and relevance of the dissertation

The topic of the dissertation is dedicated to the development and research of a portable computer system for cardiac signals for analysis and evaluation of cardiac signals and relates to the field of scientific research with scientific-applied and applied nature. The dissertation structure contains an introduction, four chapters, conclusion, contributions and appendices. The volume of the dissertation is 145 pages, and it contains 60 figures and 16 tables. The volume of the individual chapters structurally and thematically corresponds to the set goals and objectives of the dissertation. The aim of the dissertation is defined by the author as: research, design and implementation of an automated system consisting of a portable device for recording cardiac signals based on photoplethysmographic technology and software for processing, analysis and evaluation of registered signals. The tasks that the author has derived from this goal further emphasize its applied orientation.

The principle of assessment of cardiac signals in the present dissertation is based on photoplethysmographic (PPG) technology. From the comparative analysis between ECG and PPG methods for recording cardiac information, the author came to the conclusion that PPG method is an alternative to ECG and is widely used in medicine and everyday life of patients due to its simplicity and ease to receiving signals, such as the technology used makes it possible to provide an alternative measurement of a number of functional indicators related to cardiac diagnostics. PPG based devices can be designed as portable devices to be worn by the user in everyday life, providing unobtrusive health monitoring. The implementation and use of portable devices has increased diagnostic capabilities compared to stationary tools for analysis of cardio signals. The work of the doctoral student is also in this direction, and the author has focused his efforts on the realization of a portable device with PPG technology.

The PhD student has developed a new device operating in the following two modes: the passage of light through the tissue using a discrete sensor that is external to the device and is in the form of a clip; reflection of light from the fabric through an integrated sensor built into the device itself. The implemented device combines the most modern sensors, software and hardware (ARM Cortex processor, etc.), as well as the application of methods for mathematical processing and analysis of cardiac data obtained from the implemented device.

The specific applications are related to the creation of a portable device with PPG technology and a new experimental wireless sensor network for remote monitoring of patients with cardiovascular disease and give me reason to point out the relevance of the dissertation as indisputable, both scientifically and purely applied attitude.

2. Research methodology in the dissertation

The methods and methodologies used in the dissertation can be divided into the following areas: methods for extracting information about the activity of the cardiovascular system, electrocardiographic method, methods for recording ECG signals, photoplethysmographic (PPG) method, comparative analysis between ECG and PPG methods, variability analysis of heart rate. Linear and nonlinear analysis, time domain analysis, frequency domain analysis, Poincare analysis, DFA analysis, linear and nonlinear HRV analysis were also applied.

The application of linear analysis is related to mathematical analysis of heart rate, which allows not only to determine the values of statistical indicators of HRV, but also to present it in graphical form. Applying spectral analysis or analysis in the frequency domain, the doctoral student separates/decays a signal into a finite number of sinusoidal and cosine waves, which consists of the input signal to be measured and processed in the dissertation. The methods applied by the doctoral student are aimed at forming a parametric and graphical assessment of the health status of patients through experimental software for mathematical analysis of cardiac data.

3. Contributions (scientific, scientific-applied, applied) of the thesis

The contributions presented in the dissertation are seven and can be classified as scientific-applied and applied. I accept in principle the claims for contributions formulated in the dissertation by the author Eng. Krassimir Yordanov Cheshmedzhiev. Three of the contributions can be considered as scientific-applied, and four as applied. All of them are mainly related to the development of existing knowledge and derivation of new useful methods, as well as the offer of new models and practical devices for analysis and evaluation of cardiac signals.

Scientific-applied contributions:

- 1. New algorithms for pre-processing of registered ECG and PPG signals have been developed, including conversion of the analog signal into digital, low-frequency and high-frequency filtering, determination of RR (PP) interval series.
- 2. The algorithms for pre-processing of registered ECG and PPG signals have been programmatically adapted.
- 3. Based on the application of the photoplethysmographic method, a new portable device for recording cardiac signals with the possibility of its positioning on different parts of the human body has been implemented and analyzed.

Applied contributions:

- 4. A new communication protocol has been proposed for a two-way connection between the portable photoplethysmography device and a personal computer
- 5. By applying linear and nonlinear mathematical methods, software for analysis of heart rate variability has been proposed, built on a modular principle, allowing the addition of additional functional capabilities.
- 6. Based on wireless sensors, a wireless sensor network has been proposed and implemented for remote monitoring of patients with cardiovascular diseases and registration of data types such as: RR and PP interval series, temperature, number of steps, SPO2.
- 7. Experimental studies of the proposed new portable PPG device have been translated in order to validate its parameters by comparison with a second reference method electrocardiogram.

4. Publications and citations of publications on the dissertation

The main results obtained in the dissertation are presented in eight scientific publications in the period of 2018 - 2021, one of which is independent. A reference in the scientific database Scopus shows that the author eng. Krassimir Yordanov Cheshmedzhiev has:

- Hirsch index equal to 2 (h = 2);
- six (6) indexed publications, of which: two publications in journals with impact factor with a level IF = 2,679 and IF = 3,706 respectively; two in journals with impact rank with a level respectively SJR = 0.18 and SJR = 0.2; two publications that are only indexed;
- nine citations (there are 11 in the reference, 2 of which are self-citations), all of which are in refereed editions with impact rank in the range SJR = (0.192 0.772). Seven (7) of the registered citations were made by authors abroad.

For the present procedure, the candidate has submitted a reference with 10 citations of his works, of which seven (7) are in indexed editions and three (3) are in non-indexed editions.

I am convinced that the doctoral student's dissertation publications contain the main contributions that are claimed. This corresponds to the requirements of the Act on Development of the Academic Staff in the Republic of Bulgaria and the regulations for the development of the academic staff in Bulgarian Academy of Sciences for publishing the most essential parts of the dissertation.

5. Authorship of the obtained results

I have no doubt in the authorship of the results obtained and I have no information about the borrowing or use of foreign ideas, methods, results, etc. by the doctoral student. The PhD student participates in the procedure with a total of 8 publications, one (1) of which is independent and seven (7) are co-authored (in two of them, the candidate is in first place). The style and content of these works correspond to the dissertation and the abstract. The content of the presented publications is a certificate for in-depth knowledge, skills and is a prerequisite for formulating and solving current scientific and applied tasks. This gives me reason to believe that the results and contributions presented in the dissertation are his personal work.

6. Critical notes and recommendations

I have no general and normative remarks on the submitted dissertation and documents for participation in the procedure by the PhD student. I accept the abstract in the form in which it is presented, as I believe that it corresponds and sufficiently reflects the content of the dissertation. I recommend to the PhD student to continue his future work in the field of analysis and application of methods and models for evaluation of cardiac signals and to improve his implemented electronic systems for measuring and processing signals from PPG technology.

7. Conclusion

I believe that the presented dissertation meets the requirements of the Act for the development of the academic staff in the Republic of Bulgaria and the regulations for its application. The achieved results give me reason to confidently propose eng. Krassimir Yordanov Cheshmedzhiev to obtain the scientific and educational degree "Doctor" in the field of higher education - 5. Technical sciences, in the professional field - 5.2. Electrical engineering, electronics and automation, scientific specialty - 02.21.01. "Elements and Devices of Automation and Computer Engineering".

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