

Review

by Velislava Noreva Lyubenova, DSc

Professor at Institute of Robotics, Bulgarian Academy of Sciences (BAS)

on the Thesis for awarding educational and scientific degree PhD under the Scientific Field 5
Technical Science, Professional Field, Electrical Engineering, Electronics and Automation "in
the science speciality "Elements and Devices of Automation and Computer Technology"

Theme of PhD thesis: Portable Computer System for Cardiac Signals
Author of PhD thesis: Krasimir Jordanov Cheshmedjiev

1. Short biographical information

Chief Assistant Eng. Krasimir Jordanov Cheshmedjiev graduated from the Technical University, Gabrovo, with the master'degree in "Electrical engineering". From 2010 to 2017 he worked as a Chief Assistant at the Institute of Systems Engineering and Work, BAS, Section Modeling and Fractal Analysis of Information Systems, Complexes and Networks. Since 2017 he has been working at the Medical Robotics Section of IR-BAS in the same position.

2. General description of the submitted materials

As a member of the jury I received:

- ✓ Order No. 85 / 30.12.2021 of the Director of the Institute of Robotics-BAS;
- ✓ Professional CV according to European standards;
- ✓ Diploma of higher education;
- ✓ List of publications on the topic of the dissertation;
- ✓ Copies of publications on the topic of the dissertation;
- ✓ List of noticed citations;
- ✓ Contributions;
- ✓ Declaration of originality;
- ✓ Reference for exams and received credits;
- ✓ Order for enrollment in doctoral studies;
- ✓ Author's summary of PhD Thesis;
- ✓ PhD Thesis.

3. Relevance, purpose and tasks of PhD Thesis

The dissertation is in a topical and significant field related to the study of the functioning and prognosis of the cardiovascular system and in particular to the design, implementation and research of an automated system for recording, processing and analysis of cardiac signals and data.

The goal of the dissertation is research, design and implementation of an automated system consisting of portable device for recording cardiac signals based on photoplethysmographic technology and processing software for analysis and evaluation of the registered signals.

To achieve the main goal, 7 tasks are set, which are consistently solved in the dissertation. They are related to solving two problems. One is standardization - currently only linear methods for analyzing heart rate variability (HRV) are standardized, while nonlinear methods are in the process of being studied. The second problem is related to the need for portable devices for recording cardiac signals that are convenient and easy to use by the patient.

4. General characteristics of of PhD thesis

The dissertation has a volume of 145 pages and contains 4 chapters, 18 tables, 54 figures, 128 titles for the literature review, list of abbreviations, list of publications related to the dissertation, contributions, citations and appendices.

Chapter 1 includes a literature review, which presents in detail the various methods for obtaining cardiac signals and data, considering the two main methods - electrocardiographic and photoplethysmographic. A comparative analysis was made between them, devices and software for analysis of cardiac signals, as well as methods for their pre-processing were considered.

In Chapter 2 the design and construction of a photoplethysmographic (FPG) device for recording cardiac signals are presented detaily. The main components of the device and their principle of operation are shown. The advantages and limitations of the developed FPG device are indicated. The conclusions of Chapter 2 concern the advantages of photoplethysmographic technology and portable devices in cardiac diagnostics, as well as the new communication protocol for two-way communication between the presented new device for recording photoplethysmographic signals and personal computer for storage, mathematical processing and analysis of cardiac data.

Chapter 3 discusses the functionality of the software program for heart rate variability analysis. A block diagram of the software system is presented, as well as algorithms for pre-processing of ECG and FPG signals. Methods for analyzing heart rate variability are presented, and linear and nonlinear methods are discussed in detail. A software program of Visual C ++ and QT has been created, running under the Windows operating system. Software for analysis of HRV of RR / PP signals has been developed. The program allows to select a file with input data, after which they are analyzed. The results are presented in two ways: tabular and graphical. The conclusions are related to the originality of the proposed software system for pre-processing and analysis of cardiological data obtained by 3 types of cardiac data: electrocardiograph, holter or photoplethysmography device. The fact that it is open source allows to add new mathematical methods for analysis of HRV.

In Chapter 4 the created experimental base for simultaneous (synchronous) recording of ECG and FPG signals and their comparative analysis in terms of the accuracy parameter are presented. The analysis was performed using software created by the author.

The research uses a rich set of cardiac data registered in different medical institutions through different types of holter devices. The results of the analysis of HRV in the time and frequency domain are presented.

The developed portable device is applied in an experimental wireless sensor network for remote monitoring of the cardiac condition of patients through registration, mathematical analysis and evaluation of cardiac signals. This way of monitoring patients is especially suitable when they are in small settlements where there is no medical facility.

5. Contributions

I accept all contributions of the doctoral student, namely:

Scientific and applied contributions

- 1. A new portable device for recording cardiac signals has been created, based on a photoplethysmographic method with the possibility of positioning it on different parts of the human body (fingers and ear).
- 2. New algorithms for pre-processing of registered ECG and FPG signals have been developed, including: conversion of the analog signal into digital, low-frequency and high-frequency filtering, determination of RR (PP) interval series.
- 3. A new communication protocol has been created for two-way communication between the portable photoplethysmography device and a personal computer

Applied contributions

- 4. The algorithms for pre-processing of the registered ECG and FPG signals are programmatically implemented.
- 5. Software for analysis of heart rate variability using linear and nonlinear mathematical methods has been developed, which is built on a modular principle and allows additional functionality to be added if necessary.
- 6. To validate the created new portable FIG device, experimental studies have been performed on its operation by comparison with a second reference method electrocardiogram.
- 7. An experimental wireless sensor network was created for remote monitoring of patients with cardiovascular diseases, using wireless sensors to record data: RR and PP interval series, temperature, number of steps.

In my opinion, the contributions are more than sufficient in terms of quality and quantity and are related to publications in prestigious journals.

6. Author's ummary of PhD Thesis and publications related to PhD Thesis

The presented author's summary of PhD Thesis presents reliably the content of the dissertation and complies with the requirements of ZRASRB and PP ZRASRB. The report on the necessary credits

for the defense of the dissertation shows that at the required minimum of 250, the doctoral student has collected 322 credits.

The number and quality of the publications related to the dissertation make a very good impression. They are 8 in number, 2 of them with IF (3.7 and 2.7), 2 with SJR, 1 is from an international conference refereed in web of science 1 chapter of a book and 1 publication in a peer-reviewed international conference.

7. Opinion, recommendations, remarks

The dissertation is excellently structured, the main results are clearly presented and illustrated with figures, tables, appendices. The content of the dissertation meets all the requirements for obtaining the scientific degree "Doctor".

I want to express my excellent impression of the dissertation of Eng. Chesmedjiev. A lot of research work has been done with scientific-applied and applied contributions in a current field. The PhD student demonstrates in-depth knowledge and innovative skills in the development of a portable device that is applied in an experimental wireless sensor network, allowing remote monitoring of patients' cardiac status. This makes the dissertation especially significant in terms of application.

I have no significant remarks on the dissertation. I note that Eng. Chesmedjiev reflected in the dissertation my remarks from the pre-defense, which were technical. Contributions have also been adjusted towards reduction and less specificity.

8. Conclusion with a clear positive or negative assessment of the dissertation

In the PhD thesis are obtained scientific-applied and applied results, which represent an original contribution to science, are published in renowned specialized scientific journals and presented at prestigious international scientific forums.

The dissertation of Eng. Chesmedjiev meets the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria, the Regulations for its implementation, the Regulations of BAS, as well as the Regulations for the development of the academic staff of the Institute of Robotics at BAS for obtaining the educational and scientific degree "Doctor".

Based on the analysis I give a positive assessment of the presented dissertation and propose the Scientific Jury to award the Educational and Scientific degree "Doctor" to Ch. Assistant Eng. Krassimir Yordanov Chesmedjiev in Scientific Field 5 Technical Science, Professional Field , Electrical Engineering, Electronics and Automation", the science speciality "Elements and Devices of Automation and Computer Technology".

28.02.2022 Sofia Signature: