Novel Algorithms for Cardiovascular Parameters' Estimation for Long Term Monitoring Systems

By

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

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Publications arising from this thesis

Book Chapters:

1. Adel A. Al-Jumaily and Moha'med O. Al-Jaafreh, *Multi – Agent System Concepts: Theory and Application Phases*, Chapter 19 in Book: Mobile Robots: Moving Intelligence, Edit by: Jonas Buchli, ARS International, pp.: 369-392, 2006.
2. Moha'med O. Al-Jaafreh and Adel A. Al-Jumaily, *Blood Pressure Estimation with Considering of Stroke volume Effect*, Encyclopedia of HealthCare Information Systems, N. Wickramasinghe and E. Geisler, Eds.: Idea Group Inc. (IGI Global), pp.: 965-971, 2008.

Conference Papers:

3. Moha'med O. Al-Jaafreh and Adel A. Al-Jumaily, "Type-2 Fuzzy System Based Blood Pressure Parameters Estimation," *2nd Asia International Conference on Modelling and Simulation (AMS 2008)*, May 13 – 15, 2008, Kuala Lumpur, Malaysia, pp.: 953-958, 2008.
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List of Abbreviations (Acronyms)

ABP	Arterial Blood Pressure
AHA	American Health Association
AC	Alternated Current
BPP	Blood Pressure Parameters
BP	Blood Pressure
B&A	Bland & Altman Plot
CPLTMS	Cardiovascular Parameters Long Term Monitoring System
CO	Cardiac output
DBP	Diastolic Blood Pressure
DC	Direct Current
ECG	Electric cardio graph
EDBP	Estimated Diastolic Blood Pressure
EIP	Electrical Impedance Plethysmography
EMAP	Estimated Mean Arterial Blood Pressure
ESBP	Estimated Systolic Blood Pressure
HbO_2	Oxy-hemoglobin
Hb	De-Oxy-hemoglobin
HR	Heart rate
Hz	Hertz (frequency unit)
I	Circuit Current
IT2FS	Interval Type 2 Fuzzy System
LED	Light Emitting Diode
MAP	Mean Arterial blood Pressure
MF	Membership Function

ml	mile litre
mmHg	mile meter of Mercury (pressure unit)
MPSO	Multi-Particle Swarm Optimization
OS	Oxygen Saturation
PMF	Primary Membership Function
PPG	Photo-Plethysmography
PSO	Particle Swarm Optimization
SBP	Systolic Blood Pressure
SD	Standard Deviation
sec	Second
S_pO_2	Oxygen Saturation
SV	Stroke Volume
T1FS	Type 1 Fuzzy System
T2FS	Type 2 Fuzzy System
TPR	Total Peripheral blood vessel's Resistance
V	Velocity

Abstract

In daily life every person needs continuous monitoring of temperature, heart rate, oxygen saturation level, blood pressure parameters and other parameters to have some idea about one's body systems performance and to assist doctors to diagnose one's health status. This information is more necessary for aged and unhealthy people, while it is also necessary for healthy person, who represents the undiagnosed subject.

Usually, the healthy and unhealthy subjects are advised to measure their cardiovascular parameters at home at various times in a day to avoid any bad developments for their health status. Available self-measurement devices give only discrete readings and have not provided accurate information of heart rate, oxygen saturation level, and blood pressure parameters in many situations since most of them do not consider the body's movement or the uncertainty associated with the reading.

Moreover, Blood pressure parameters (BPP): Systolic, Diastolic, and Mean Blood Pressures, have some types of correlation with the heart rate. This relationship is nonlinear and has many levels of uncertainty. The Type-2 Fuzzy system has a capacity to deal with nonlinear and uncertainty systems. The estimate of Blood pressure parameters based on heart rate can be categorized under such systems that fuzzy system can deal with.

This thesis presents a novel algorithm to measure photo-plethysmography signal, heart rate and the oxygen saturation level and also to estimate BPPs for healthy and unhealthy subjects based on a prototype transducer, particle swarm optimization and type-2 Fuzzy System.

The measured values of heart rate, oxygen saturation level, systolic, diastolic and mean blood pressures by utilizing the novel algorithm are compared with the clinical readings of heart rate, oxygen saturation level, systolic, diastolic and mean blood pressure.

Very encouraging results have been achieved for estimating heart rate, oxygen saturation level, systolic, diastolic and mean blood pressures and the accuracy of estimated results for that parameters for healthy subjects, by our designed algorithm, are 99.53%, 98.91%, 97.76%, 91.81% and 96.43%, respectively.

Add to that, the accuracy of estimated results systolic, diastolic and mean arterial blood pressure for unhealthy subjects are 94.51%, 91.48% and 94.79%, respectively.

On the contrary, the mean arterial blood pressure is estimated based on same heart rate and existing algorithm. This algorithm can only estimate mean arterial blood pressure. The accuracy of estimated mean arterial blood pressure equals 53.83%.

The proposed model achieves very encouraging results; since all accuracies of the blood pressure parameters for unhealthy and healthy subjects are more than 91.4%. Moreover, the proposed algorithm can be utilized to determine heart rate, oxygen saturation level, systolic, diastolic and mean blood pressures.