

**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:**

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### **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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## Table of Contents

Chapter 1.	Introduction .....	1
1.1.	Background .....	1
1.2.	Motivation .....	2
1.3.	Objectives.....	3
1.4.	Problem statement.....	4
1.5.	Contribution .....	5
1.6.	Thesis Structure.....	5
1.7.	Summary .....	6
Chapter 2.	Cardiovascular system .....	7
2.1.	Introduction .....	7
2.2.	Hypertension .....	10
2.2.1.	Factors cause Hypertension.....	10
2.2.2.	Diseases due to Hypertension .....	11
2.3.	Hypotension .....	12
2.3.1.	Factors causing Hypotension .....	12
2.3.2.	Diseases due to Hypotension .....	13
2.4.	Prevention .....	13
2.5.	Summary:.....	14
Chapter 3.	Current methods to measure cardiovascular parameters.....	15
3.1.	Introduction.....	15
3.2.	Heart sound .....	15
3.3.	Blood level “arterial cannulation” .....	16
3.4.	Pulses and external pressure .....	19
3.4.1.	Palpation method.....	19

3.4.2.	Auscultatory method .....	20
3.4.3.	Oscillometric method .....	22
3.4.4.	Local pressurization methods.....	22
3.5.	Pulse arrival time.....	27
3.6.	Existing proposed methods based on photo-plethysmogram signal .....	30
3.6.1.	Existing proposed methods to measure Oxygen Saturation Level .....	31
3.6.2.	Existing proposed methods to measure Blood pressure.....	32
3.7.	Summary .....	41
Chapter 4.	Intelligent Techniques .....	42
4.1.	Introduction.....	42
4.2.	Interval Type-2 Fuzzy system .....	43
4.2.1.	Type-1 Fuzzy System.....	43
4.2.2.	History and Theory of Interval Type-2 Fuzzy System .....	48
4.2.3.	Parts of Interval Type-2 Fuzzy System .....	49
4.2.4.	Applications and benefits of Type-2 Fuzzy System.....	52
4.3.	Particle Swarm Optimization .....	54
4.3.1.	History and theory of Particle Swarm Optimization.....	54
4.3.2.	Parts of Particle Swarm Optimization.....	55
4.3.3.	Applications and benefits of Particle Swarm Optimization.....	59
4.4.	Summary .....	60
Chapter 5.	Cardiovascular Parameters Long Term Monitoring System .....	61
5.1.	Introduction:.....	61
5.2.	Photo-plethysmography signal.....	62
5.3.	Second level of Cardiovascular Parameters .....	65
5.3.1	Heart rate.....	65

5.3.2	Pulse wave velocity.....	69
5.3.3	Oxygen Saturation.....	70
5.4.	Summary .....	77
Chapter 6.	Blood Pressure Estimations Methods .....	78
6.1.	Introduction.....	78
6.2.	Mean arterial blood pressure estimation methods.....	78
6.2.1.	Carr's expression.....	79
6.2.2.	Proposed Methods.....	84
6.2.3.	Optimizing A, $SV_0$ and TPR by Multi PSO.....	95
6.3.	Utilize type-2 Fuzzy for Blood pressure parameters estimation.....	101
6.3.1.	Estimating BPPs for Unhealthy subjects .....	105
6.3.2.	Estimating BBP for Healthy subjects.....	120
6.4.	Summary .....	130
Chapter 7.	Conclusion and Future research .....	131
7.1.	Experiments' results of Heart rate.....	131
7.2.	Experiments' results of oxygen saturation level .....	132
7.3.	Experiments' results of mean arterial blood pressure .....	132
7.4.	Experiments' results of systolic blood pressure.....	134
7.5.	Experiments' results of diastolic blood pressure .....	135
7.6.	Future work .....	137
8.	Appendix .....	138
	Ethical report:.....	138
9.	References .....	139



## List of Figures

### Chapter 2

Figure 2.1: Schematic representation of pulmonary and systemic circulations [7] ..... 8

Figure 2.2: Pressure drop in the circulatory system [8]..... 9

### Chapter 3

Figure 3.1: Stethoscope's Forms ..... 16

Figure 3.2:Hale's method [11]..... 17

Figure 3.3: Kymograph..... 18

Figure 3.4: Palpation method ..... 19

Figure 3.5: Sphygmomanometer ..... 21

Figure 3.6: Korotkoff's characteristic sounds and auscultatory method ..... 21

Figure 3.7: Volume-Compensation method ..... 23

Figure 3.8: Volume-Oscillometric method..... 25

Figure 3.9: Local pressurization instruments ..... 26

Figure 3.10: QRS apex of R wave and onset point of PPG signal ..... 29

Figure 3.11 Photo-plethysmography Types ..... 31

Figure 3.12: PPG signal..... 31

Figure 3.13: Ring sensor..... 33

Figure 3.14: Artery Model and parameters of four Hemodynamic models..... 33

Figure 3.15: Wireless ring sensor ..... 34

Figure 3.16: Wearable sensor ..... 36

Figure 3.17: PPG signals ..... 37

Figure 3.18: Photo-plethysmographic features ..... 38

## Chapter 4

Figure 4.1: Crisp set MF .....	44
Figure 4.2: Type-1 MF .....	44
Figure 4.3: Block diagram of Fuzzy System.....	46
Figure 4.4: Stages of Type-1 fuzzy system .....	47
Figure 4.5: Extension Type-1 MF to Type-2 PMF .....	48
Figure 4.6: Gaussian Interval Type-2 PMF .....	49
Figure 4.7: Block diagram of Type-2 Fuzzy System .....	50
Figure 4.8: Stages of Type-2 Fuzzy System.....	51
Figure 4.10: Flowchart of Particle Swarm Optimization Algorithm.....	58

## Chapter 5

Figure 5.1: The Cardiovascular Parameters structure .....	61
Figure 5.2: Photo-plethysmography Types .....	62
Figure 5.3: Circuit Model of PPG Sensor .....	63
Figure 5.4: A proto-type of PPG sensor's circuit .....	63
Figure 5.5: PPG signal as sketched by the oscilloscope .....	64
Figure 5.6: Structure of PPG signal .....	65
Figure 5.7: Real HR and computed HR Values.....	68
Figure 5.8 B&A plot for computed HR Values .....	69
Figure 5.9 Two PPG sensor circuit and PPG signals as sketched by the oscilloscope ...	70
Figure 5.10 Graphical presentation of Beer-Lambert law .....	72
Figure 5.11: Absorption Spectrum graph for Oxy-hemoglobin and De-Oxy-hemoglobin [78] .....	73
Figure 5.12: Graphical illustration of equation (5-13).....	74
Figure 5.13: Hardware Circuit of Two PPG sensors to measure OS .....	75

Figure 5.14: Comparison between CPLTMS and standard device .....	77
Chapter 6	
Figure 6.1: The estimated MAP1 values and real MAP values .....	82
Figure 6.2: B&A plot for estimated MAP by Carr's Method.....	83
Figure 6.3: Flowchart of Fit method .....	85
Figure 6.4: The estimated MAP values of Meth2, Meth1 and real MAP values .....	87
Figure 6.5: B&A plot for MAP Values for Meth1 and Meth2 .....	88
Figure 6.6: Flowchart of PSO procedure .....	92
Figure 6.7: Mean of estimated MAP values of Meth3, Meth2, Meth1 and real MAP values.....	94
Figure 6.8: B&A plot for MAP Values for Meth3.....	95
Figure 6.9: The estimated MAP of Meth4 Meth3, Meth2, Meth1 and real MAP values .....	100
Figure 6.10: B&A plot for MAP Values for Meth4.....	101
Figure 6.11: Fuzzification of Heart Rate to five singleton Interval Type-2 fuzzy sets .	102
Figure 6.12: Fuzzification of SBP or DBP to five Interval Type-2 fuzzy sets.....	103
Figure 6.13: The estimated SBP values of trained IT2FS and real SBP values.....	110
Figure 6.14: B&A plot of ESBP Values .....	111
Figure 6.15: The estimated DBP values of trained IT2FS and real DBP values.....	113
Figure 6.16: B&A plot of EDBP Values .....	114
Figure 6.17: The estimated MAP values and real MAP values .....	116
Figure 6.18: B&A plot of EMAP Values.....	117
Figure 6.19: Mean of estimated MAP values by IT2FS, EMAP4 and real MAP values .....	119
Figure 6.20: The estimated SBP values real SBP values for Healthy Subjects .....	122

Figure 6.21: B&A plot of SBP for Healthy Subjects ..... 123

Figure 6.22: The estimated DBP values real DBP values for Healthy Subjects ..... 125

Figure 6.23: B&A plot of DBP for Healthy Subjects..... 125

Figure 6.24: The estimated MAP values real MAP values for Healthy Subjects ..... 127

Figure 6.25: B&A plot of MAP for Healthy Subjects..... 128

Figure 6.26: The estimated MAP values by Carr’s expression and real MAP values .. 129

Chapter 7

Figure 7.1 The achieved accuracies of MAP methods ..... 134

## List of Tables

### Chapter 3

Table (3-1): Statistical amounts of Chen's method .....	29
---	----

### Chapter 5

Table (5.1): DC, AC components and frequencies of AC components of PPG signal ...	64
---	----

Table (5.2): AC component frequency of PPG signal and Heart rate .....	66
--	----

Table (5.3): PPG signal frequencies and HR values for subjects of MIMIC database ...	67
--	----

Table (5.4): LEDs' Wavelengths and their corresponding Extinction Coefficient [78]..	74
--	----

Table (5.5): Experimental Values of Four Normal Subjects .....	75
--	----

Table (5.6): Comparison between CPLTMS and Standard Device.....	76
---	----

### Chapter 6

Table (6.1): mean of HR values, mean of estimated MAP1 values based on Meth1, mean of real MAP and absolute difference between real and estimated MAP1 values..	81
--	----

Table (6.2): mean of HR values, mean of real MAP, mean of estimated MAP values by Meth1 and Meth2 & absolute differences between their values of Meth1 and Meth2 ...	86
---	----

Table (6.3): mean of HR values, real MAP, estimated MAP by Meth1, Meth2 and Meth3, and absolute differences between mean of real and estimated MAP by Meth1, Meth2 and Meth3 .....	93
--	----

Table (6.4): mean of HR values, real MAP, estimated MAP by Meth4 and absolute differences between real and estimated MAP by Meth4.....	99
---	----

Table (6.5): Mean of HR and BPPs values of patient subjects .....	105
---	-----

Table (6.6): ESBP values, HR values, Real SBP values for remaining ten subjects and the absolute differences between ESBP and Real SBP.....	108
--	-----

Table (6.7): EDBP values, HR values, Real DBP values for remaining ten subjects and the absolute differences between EDBP and Real DBP .....	112
---	-----

Table (6.8): EMAP values, HR values, Real MAP values for remaining ten subjects and the absolute differences between EMAP and Real MAP.....	115
Table (6.9): Mean of EMAP4 values, HR values, Real MAP values for remaining ten subjects and the absolute differences between EMAP and Real MAP .....	118
Table (6.10): Average of HR and BP readings of Normal subjects.....	121
Table (6.11): Estimated SBP for remaining ten normal subjects .....	122
Table (6.12): Estimated DBP for remaining ten normal subjects.....	124
Table (6.13): Estimated MAP for remaining ten normal subjects.....	126
Table (6.14): EMAP values, HR values, Real MAP values for remaining ten subjects and the absolute differences between EMAP and Real MAP .....	129

## 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 <sub>2</sub>	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 <sub>p</sub> O <sub>2</sub>	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.