

**MEASUREMENT AND ANALYSIS OF  
PHYSIOLOGICAL PARAMETERS  
USING SIGNAL PROCESSING  
TECHNIQUES**

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**THESIS SUBMITTED IN FULFILLMENT  
FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY**

PERPUSTAKAAN  
UNIVERSITI MALAYSIA SABAH

**FACULTY OF ENGINEERING  
UNIVERSITI MALAYSIA SABAH  
2018**



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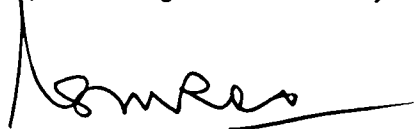
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## DECLARATION

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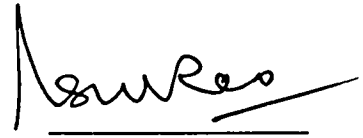
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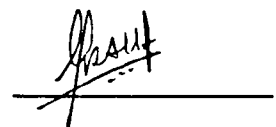
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## ACKNOWLEDGEMENT

First and foremost, I would like to pen down a special note to thank my main supervisor, Prof. Dr. Nittala Surya Venkata Kameswara Rao for his unsparing supports, brilliant guidance, advice, inspiration, opportunities, encouragements and great vision throughout the thesis work. The excellent supervision, great ambition, patience and professionalism of Prof. Dr. Nittala Surya Venkata Kameswara Rao have guided me to attempt the interesting of research work.

My heartfelt appreciation also goes out to my co-supervisor, Ir. Dr. Muralindran Mariappan for giving me an opportunity to learn from him. With his expertise, supportability, motivation and timely suggestions, this work has been successfully published. With his kindness, Ir. Dr. Muralindran Mariappan not only guided me in my research, he also directed me to live with a thankful heart.

I hereby sincerely acknowledge both of my great supervisors for spending their valuable time on my research without any delay and willing to share their precious knowledge with me without any closeness.

I equally thank to the Ministry of Higher Education for the financial supports. This doctoral thesis would not have been possible without the availability of the scholarships from MyPhD under program MyBrain15. I also sincerely thank to the Ministry of Education for funding the research grant FRG0350-TK-2/2013, without the equipment provided by the grant, this thesis would not be this fruitful.

My acknowledgement also goes to the Universiti Malaysia Sabah especially Faculty of Engineering, where is the place for me to earn my Bachelor Degree, Master Degree and Doctoral Degree. Furthermore, I would like to thank the Dean of Faculty of Engineering, Universiti Malaysia Sabah, Prof. Ir. Dr. Abdul Karim bin Mirasa for providing me the research lab and facilities so that I can conduct my experiments to success this research study. My thankfulness also goes to all lecturers of Faculty of Engineering, who taught me before during all these years of studying in Universiti Malaysia Sabah.

I am very grateful to Postgraduate Coordinator, Faculty of Engineering, Universiti Malaysia Sabah, Dr. Abu Zahrim bin Yaser for his willingness to lend a helping hand when I am facing difficulties on my research. I also gratefully acknowledge Prof. Dr. Ali Chekima for his kindness to provide me suggestions and advice on my research proposal. His invaluable opinions have always benefited my research study.

I would like to thank Mr. Vigneswaran Ramu, who is also my scholar colleague for providing the sale service of NI-LabVIEW instruments. His invaluable opinion and information regarding the NI-LabVIEW products have benefited my research works.

My sincerely thanks are extended to Polyclinic Universiti Malaysia Sabah and KMC Medical Centre for providing me the facilities to conduct the electrocardiogram



(ECG) test. I equally thank Dr. Amy Chong Yee Min from Putri Health and Wellness Centre Pantai Hospital Ipoh for helping me to conduct the blood test. With the doctors' and nurses' assistances, I successfully conducted the tests for evaluating the findings of my research.

Sincere thanks go to the participants, my grandmother, Mdm. Woo Ah Ng, my niece, Ms. Seow Pui Mun, scholar colleague, Mr. Nicklos bin Jefrin and the undergraduate students, Mr. Lu Gwan Hou, Mr. Liew Vun Ken, Mr. Kong Chun Keong, Mr. Rooster Mr. Lim Yong Zhi, Mr. Lui Ming Cheng, Mr. Tan Min Yao, Mr. Tang Kee Cheong, Mr. Kuan Zheng Cang, Mr. Lim Kean Boon, Mr. Chai Kah Fei, Mr. Sin Chong Huat and Mr. Tang Nyiak Tien for their voluntary to enlarge and enrich the samples of this doctoral thesis.

Certainly not to forget my deepest gratitude that specially reserves for my parents, Mdm. Teh Lea Ling and Mr. Khong Weng Lek, my sister, Ms. Khong Mei Wan and my uncle, Mr. Khong Weng Keong for giving me endless encouragement, backing and sacrifice during my study. Their supports are beyond words and I forever grateful for everything they have done and owe them a debt that can never be a repaid.

Last but not least, I am greatly indebted to my life partner, Dr. Chong Chee Siang, who also my scholar colleague for her willingness in giving me supportability, motivation and discussion on my research works. Her encouragement and tolerance also have brightened my life when I am in the darkness. My deep gratitude also goes to her family members, Mr. Chong Tham Yoon, Mdm. Ng Ooi She, Ms. Chong Chee Yin, Mdm. Chong Chee Foong and Mr. Gary Walsh for always supporting me.

Khong Wei Leong  
18<sup>th</sup> December 2017



## ABSTRACT

Health is very essential in everyone's life but to always stay healthy, it becomes a very challenging task especially for the citizens of developing countries. To have a good health, it is important to monitor the physiological parameters such as heart beat rate/pulse rate, blood pressure, blood oxygen saturation level, respiration rate, temperature and hemoglobin concentration frequently. Nowadays, there are many health care devices that have been developed for measuring physiological parameters but most of them are with limited parameter measurements, a single subject assessment and inconvenient for continuous measurements monitoring due to their contact basis. Furthermore, most of the devices require well-trained health professionals to operate because the sensors of the devices are to be attached to specific body part for acquiring data. Hence, these drawbacks make the devices suitable to be used at health care centers only. As an alternative approach, this research is focused on extracting physiological parameters through video image processing techniques using ordinary RGB camera. With a recorded video of about 10 seconds, it is possible to analyze multiple physiological parameters simultaneously. The physiological parameters that are extracted in this research include the vital signs i.e. heart beat rate/pulse rate, blood pressure and blood oxygen saturation level and two other physiological parameters i.e. hemoglobin concentration and skin surface profile. For evaluation of the results, electrocardiogram (ECG), pulse oximeter, oscillometric device and complete blood count (CBC) test are used to evaluate the results obtained from the developed video image processing techniques. From the results, it shows that the pulse rate measurements are quite accurate and within the American National Standard (ANSI/AAMI EC:13:2002) that is  $\pm 5$ bpm or 10% readout error. Besides, the pulse rate results obtained from the proposed method are able to correlate with ECG, pulse oximeter and oscillometric device by achieving correlation coefficient of 0.96, 0.97 and 0.95 respectively. In terms of blood pressure measurement, the mean absolute error and standard deviation for systolic and diastolic pressure from collected data is  $4.45 \pm 3.05$ mmHg and  $4.57 \pm 3.30$ mmHg respectively. These values also fulfill the requirement set by American National Standard (ANSI/AAMI/ISO 81060-2:2013), which is  $5 \pm 8$ mmHg. Furthermore, the correlation coefficient between the proposed method and oscillometric device is 0.81 and 0.78 for systolic and diastolic blood pressure respectively. For the blood oxygen saturation level measurements, the accuracy root mean square error ( $A_{RMS}$ ) is 1.26% which is also able to accomplish the accuracy set in the International Standard ISO 9919:2005 and ISO 80601-2-61-2011. By comparing the hemoglobin concentration obtained from the proposed method to the CBC test, the estimated hemoglobin concentration for the 2 participants are able within the difference of 1 g/dL. Although there is no standard equipment available for the evaluation of surface profile in this research, the developed method is evaluated by using the manual visual inspection approach and the findings of Ondimu and Murase's study. From the results, it shows that the developed method is feasible to estimate skin surface profile. In conclusion, the developed video image processing techniques for extracting multiple physiological parameters simultaneously are very beneficial and promise high potential due to its non-contact basis, harmless and suitable for continuous monitoring. Besides, developing the techniques as a smartphone app



would make it more convenient to operate, economical and reduce the white coat effects, which cause the nervousness when measurements are taken by health professional.





## **ABSTRAK**

### **PENGUKURAN DAN ANALISIS BACAAN FISILOGI DENGAN MENGGUNAKAN TEKNIK ISYARAT PEMROSESAN**

Kesihatan adalah sangat penting dalam kehidupan setiap orang tetapi untuk sentiasa kekal sihat, ia menjadi satu tugas yang sangat mencabar terutamanya bagi rakyat di negara yang sedang membangun. Untuk mempunyai kesihatan yang baik, adalah penting untuk memantau bacaan fisiologi seperti kadar degupan jantung/nadi, tekanan darah, kadar oksigen dalam darah, kadar pernafasan, suhu dan kepekatan hemoglobin dengan kerap. Kini, terdapat banyak peranti penjagaan kesihatan telah dihasilkan untuk mengambil bacaan fisiologi tetapi kebanyakan peranti hanya memberi bacaan yang terhad, hanya seorang subjek dapat dinilai dan tidak sesuai untuk pemantauan bacaan berterusan kerana ia mengambil bacaan berdasarkan penyentuhan. Tambahan pula, kebanyakan peranti memerlukan pegawai kesihatan yang terlatih untuk mengendalikannya kerana pengesanan peranti perlu diletakkan pada bahagian badan tertentu untuk memperoleh data. Oleh itu, kelemahan-kelemahan ini menyebabkan peranti lebih sesuai digunakan di pusat penjagaan kesihatan. Sebagai kaedah alternatif, kajian ini memberi tumpuan kepada pengekstrakan bacaan fisiologi melalui teknik pemprosesan video imej dengan menggunakan kamera RGB biasa. Dengan video yang dirakam selama 10 saat, ia memungkinkan penganalisaan pelbagai bacaan fisiologi pada masa yang sama. Bacaan fisiologi yang diekstrak dalam kajian ini termasuk bacaan fisiologi utama iaitu kadar degupan jantung/nadi, tekanan darah dan kadar oksigen dalam darah dan dua bacaan fisiologi yang lain iaitu kepekatan hemoglobin dan profil untuk permukaan kulit. Untuk pengesahan keputusan, elektrokardiogram (ECG), nadi oksimeter, peranti oscillometrik dan ujian kiraan darah lengkap (CBC) digunakan untuk mengesahkan bacaan yang didapati daripada teknik pemprosesan video imej yang dicadangkan. Daripada hasil kajian, ia menunjukkan bahawa kadar nadi agak tepat dan dapat memenuhi American National Standard (ANSI/AAMI EC:13:2002) iaitu  $\pm 5$ bpm atau 10% bagi ralat bacaan. Selain itu, keputusan kadar nadi yang diperoleh daripada kaedah yang dicadangkan dapat dikaitkan dengan ECG, nadi oksimeter dan peranti oscillometrik dengan mencapai pekali kolerasi 0.96, 0.97 dan 0.95 masing-masing. Dari segi pengukuran tekanan darah, purata ralat mutlak dan sisihan piawai untuk tekanan sistolik dan diastolik dari data yang dikumpulkan adalah  $4.45 \pm 3.05$ mmHg dan  $4.57 \pm 3.30$ mmHg masing-masing. Nilai-nilai ini juga memenuhi syarat yang ditetapkan oleh American National Standard (ANSI/AAMI/ISO 81060-2:2013) iaitu  $5 \pm 8$ mmHg. Selain itu, pekali kolerasi antara kaedah yang dicadangkan dan peranti oscillometrik adalah 0.81 and 0.78 untuk tekanan darah sistolik dan diastolik masing-masing. Untuk pengukuran kadar oksigen dalam darah normal, ketepatan punca purata kuasa persegi ( $A_{RMS}$ ) adalah 1.26% dan ia mampu mencapai ketepatan yang ditetapkan dalam Standard Antarabangsa ISO 9919:2005 dan ISO 80601-2-61-2011. Dengan membandingkan kepekatan hemoglobin yang diperoleh daripada kaedah yang dicadangkan dengan ujian CBC, kepekatan hemoglobin yang



*dianggarkan untuk 2 peserta mampu mengekalkan dalam perbezaan 1g/dL. Walaupun tidak terdapat peralatan piawai untuk penilaian profil permukaan dalam kajian ini, kaedah yang dihasilkan akan dinilai dengan menggunakan kaedah pemeriksaan penglihatan manual dan penemuan kajian Ondimu dan Murase. Dari hasilnya, ia menunjukkan bahawa kaedah yang dihasilkan adalah sesuai untuk menganggarkan profil permukaan kulit. Sebagai kesimpulan, teknik pemprosesan video imej yang dicadangkan untuk mendapatkan pelbagai bacaan fisiologi pada masa yang sama adalah sangat bermanfaat dan menjanjikan potensi yang tinggi kerana ia mengambil bacaan secara tidak bersentuhan, tidak berbahaya dan sesuai untuk pemantauan berterusan. Selain itu, dengan membangunkan teknik-teknik sebagai aplikasi telefon pintar, ia akan lebih mudah beroperasi, lebih jimat dan dapat mengurangkan kesan kot putih yang disebabkan oleh gementar semasa pengukuran diambil oleh pegawai kesihatan.*



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## LIST OF ABBREVIATIONS

<b>AAMI</b>	Association for the Advancement of Medical Instrumentation
<b>Abs</b>	Absolute
<b>AC component</b>	Pulsatile Component
<b>Ag</b>	Silver
<b>AgCl</b>	Silver Chloride
<b>ANSI</b>	American National Standards Institute
<b>aVF</b>	Augmented Vector Foot
<b>aVL</b>	Augmented Vector Left
<b>aVR</b>	Augmented Vector Right
<b>B</b>	Blue
<b>BHS</b>	British Hypertension Society
<b>BSS</b>	Blind Source Separation
<b>bpm</b>	Beats per Minute
<b>CBC</b>	Complete Blood Count
<b>CCD</b>	Charge Coupled Device
<b>CMOS</b>	Complementary Metal Oxide Semiconductor
<b>CVDs</b>	Cardiovascular Diseases
<b>DAQ</b>	Data Acquisition
<b>DBP</b>	Diastolic Blood Pressure
<b>DC component</b>	Non-pulsatile component
<b>dB</b>	Decibels
<b>ECG</b>	Electrocardiogram
<b>FDA</b>	Food and Drug Administration





<b>FFT</b>	Fast Fourier Transform
<b>fps</b>	Frames per Second
<b>G</b>	Green
<b>ICA</b>	Independent Component Analysis
<b>ICU</b>	Intensive Care Unit
<b>IDE</b>	Integrated Development Environment
<b>JADE</b>	Joint Approximate Diagonalization of Eigen Matrices
<b>LA</b>	Left Arm
<b>LED</b>	Light Emitting Diode
<b>LL</b>	Left Leg
<b>LLDB</b>	Low Level Virtual Machine Debugger
<b>LLVM</b>	Low Level Virtual Machine
<b>MAE</b>	Mean Absolute Error
<b>MATLAB</b>	Matrix Laboratory
<b>MPE</b>	Maximum Permissible Exposure
<b>MRI</b>	Magnetic Resonance Imaging
<b>mmHg</b>	Millimeters of Mercury
<b>NADH</b>	Dihyronicotinamide Adenine Dinucleotide
<b>NI</b>	National Instruments
<b>NIBP</b>	Non-invasive Blood Pressure
<b>NI-LabVIEW</b>	National Instruments Laboratory Virtual Instrument Engineering Workbench
<b>OECD</b>	Organization for Economic Co-operation and Development
<b>OLED</b>	Organic Light Emitting Diode
<b>PCA</b>	Principal Component Analysis

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