MEASUREMENT AND ANALYSIS OF PHYSIOLOGICAL PARAMETERS USING SIGNAL PROCESSING TECHNIQUES

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DECLARATION

I hereby declare that the materials in this thesis are my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

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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 ±5bpm 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±3.05mmHg and 4.57±3.30mmHg respectively. These values also fulfill the requirement set by American National Standard (ANSI/AAMI/ISO 81060-2:2013), which is 5±8mmHg. 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 FISIOLOGI DENGAN MENGGUNAKAN TEKNIK ISYARAT PEMPROSESAN

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 pengesan 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 ±5bpm 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±3.05mmHg dan 4.57±3.30mmHg masing-masing. Nilai-nilai ini juga memenuhi syarat yang ditetapkan oleh American National Standard (ANSI/AAMI/ISO 81060-2:2013) iaitu 5±8mmHg. 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

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

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

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