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Heart Rate, Respiration Rate and Oxygen Saturation Level Monitoring from Video Recording by Smart phone camera

[1]Shruti Madan Kshirsagar, [2]Gyankamal J. Chhajed

Computer Engineering Department,
VPCOE, Pune University, Baramati, India.
[1]shruti.kshirsagar912@gmail.com, [2]gjchhajed@gmail.com

***Abstract* - Heart disease and stroke are among the world's leading causes of death and disability. The higher stress level, inactive lifestyle, unawareness about risk factors such as overweight, high cholesterol level, hypertension, diabetes etc. results in increasing risk of cardiovascular diseases. Heart patients have to follow different tests for diagnosis as well as for treatment. The presented techniques such as ECG are expensive, invasive and can be applied only under clinical observation. Development of noninvasive, accurate physiological parameter monitor which can be used at personal as well as clinical level is among the main fields in biomedical engineering. The popularity of smart phones is increasing at a very tremendous rate. A mobile phone can serve as an accurate monitor for several physiological variables, based on its ability to record and analyze the varying color signals of a fingertip placed in contact with its optical sensor. In this paper, we have used smartphone camera for collecting the PPG videos. At the same time pulse rate and oxygen saturation level is measured using standard pulse oxymeter. The patient is asked to breathe by metronome breathing technique. ICA algorithm is used for removing the motion artifact. As per the study and observations, the use of Smart phones for the estimation of the heart rate, respiration rate and oxygen saturation level is conceivable.**

***Index Terms*— PPG (photoplenthesmography), HR (heart rate), RR (respiration rate), SpO2 (oxygen saturation level), MA (motion artifact), physiological parameter monitor, pulse**

I. INTRODUCTION

Nowadays the risk factors such as obesity, hypertension and heart diseases are increasing at a tremendous rate. People are suffering from such health disorders due to unhealthy eating habits, sedentary lifestyle, lack of daily exercise and lack of proper knowledge and awareness about all these health related factors. The percentage of hypertension and diabetes in early age (i.e. between 25-35 years) is also increasing. Heart disease and stroke can affect anyone without regard to age, race, ethnicity, sex, or income level. This is harmful or can cause severe heart disease and can increase risk of cardio respiratory failure if doesn't handled properly.

As per family doctor's advice, the heart patients have to undergo different medical test after regular time interval. These tests are time consuming and costly. Some of them are performed under anesthesia. The gold standard techniques for measurement of the cardiac pulse such as the electrocardiogram (ECG) require patients to wear adhesive gel patches or chest straps that can cause skin irritation and discomfort. Commercial pulse oximetry sensors that attach to the fingertips or earlobes are also inconvenient for patients and the spring-loaded clips can cause pain if worn over a long period of time.

So the development of low-cost physiological monitoring solutions those are easy to use, accurate, and can be used in the home or ambulatory settings is one of the main research area in the field of biomedical engineering.

PPG-(photoplenthesmography) imaging technique is new milestone in the field of biomedical engineering. It is a non-invasive optical method to detect a cardiovascular pulse wave travelling through the body. This technique can be used for detecting different cardiovascular parameters such as respiration rate, heart rate, oxygen saturation level, heart variability etc.

II. LITERATURE SURVEY

A. PPG for monitoring different physiological parameters

1. PPG using multiLED light source and photo detector sensors

Monitoring of vital body signs such as heart rate and blood oxygenation via photoplethysmography (PPG) originates from early investigations of Hertzman on blood circulation in limb extremities. Early PPG devices contains multiLED light source for illuminating skin part and a photo detector is used to record the signals.

In 1964 Shaw assembled the first absolute reading ear oximeter by using eight wavelengths of light. Pulse oximetry was developed in 1972, by Takuo Aoyagi and Michio Kishi, bioengineers, at Nihon Kohden using the ratio of red to infrared light absorption of pulsating components at the measuring site. The investigations observed by Takuo Aoyagi ware the main step towards the recent oximeters. Nest generations of pulse oximeters are using PPG technology for measurement of SpO2.
Then PPG imaging is used for estimating respiration rate.This system is introduced by Ki H. Chon, Senior Member, IEEE [2].
Advantages:

1. Noninvasive technique to monitor vital physiological parameters.

2. There is no need of any contact of device with skin.
3. This technique can be used for many parameter such as heart rate, respiration rate, heart rate variability, arterial fibrillation, blood pressure, oxygen saturation level etc.

Limitations:

Those systems are very bulky and can't carry easily with us wherever required.

2. PPG using natural sunlight as a source of light and webcam of laptop as photo detector

Further studies and experiments introduces a new innovative idea,' Non-contact, automated cardiac pulse measurements using video imaging and blind Source separation' in which webcam of a computer is used as a photo detector and natural light as a illuminating source. Ming-Zher Poh, et.al.[6] proposed this technology in the year 2010.

Advantages:

1. Noninvasive method for detecting heart rate. It doesn't require any contact with the skin for monitoring heart rate unlike Existing methods i.e. Commercial pulse oximetry sensors.
2. It doesn't require any extra hardware components. Such a technology would also minimize the amount of cabling and clutter associated with neonatal ICU.
3. It can calculate heart rate of more than one subjects at a time.
4. natural source of light i.e. sun light is used for illuminating the skin.

Limitations:

1. Variations in sunlight intensity can cause decreasing SNR.
2. This technology uses the webcam available as inbuilt feature with laptop. But the quality of videos can undergo changes due to different resolution of a camera.

3. PPG using inbuilt smart phone camera as photodetector and LED flash as a source of light

The recent application using PPG technique is developed by a team led by Ki Chon, professor and head of biomedical engineering at WPI. They have developed a smart phone application that can measure not only heart rate, but also heart rhythm, respiration rate and blood oxygen saturation using the phone's built-in video camera. The new application yields vital signs as accurate as standard medical monitors now in clinical use [9].

There are a few colleagues participating this app development including Yitzhak Mendelson, associate professor of biomedical engineering, Domhnull Granquist-Fraser, assistant professor of biomedical engineering. The researchers are also developing an application to detect arterial fibrillation, the most common form of cardiac arrhythmia, and a version for tablets like the iPad2.

B. Approaches for motion artifact reduction from recorded PPG signals

1. MA reduction by using traditional approaches

Rajet Krishnan,, alasubramaniam Bala Natarajan, and Steve Warren, proposed Two-Stage Approach for detection and reduction of motion artifacts in photoplethysmographic data in 2010. They present novel and consistent techniques to detect the presence of motion artifact in PPGs given higher order statistical information present in the data.

J. G. Webster, M. R. Neuman and N.Wang, K. W. Chan and Y. T. Zhang, J. Lee, W. Jung, I. Kang, Y. Kim, and G. Lee proposed that The moving average (MA), adaptive, and multi rate filtering techniques for MA reduction.

Limitation - These techniques have limited scope and not suitable for estimation of every physiological parameters. C. M. Lee and Y. T. Zhang, B. S. Kim and S. K. Yoo, proposed Wavelet transform technique in 2005.

Limitation - Studies indicated that the arterial pulsations are not statistically independent from motion.

2. MA reduction using ICA

Aapo Hyvrinen and Erkki Oja (research scientist –Neural Networks Research centre ,Helsinki University of Technology ,Finland) proposed ICA technique for signal separation in their research paper "Independent Component Analysis: Algorithms and Applications"[13].

Byung S. Kim and Sun K. Yoo [14] stated that the combination of independent component analysis and block interleaving with low-pass filtering can reduce the motion artifacts under the condition of general dual-wavelength measurement in their IEEE transaction paper named "Motion Artifact Reduction in Photoplethysmography Using Independent Component Analysis[2006]". Preprocessing PPG signal followed by ICA gives more accurate results.

Ming-Zher Poh, Daniel J. McDuff, and Rosalind W. Picard proposed the novel approach which can be applied to PPG color video recordings of the human face and is based on automatic face tracking along with blind source separation of the color channels into independent components[may 2010].

Advantages:

1. This is the first demonstration of a low-cost accurate video-based method for contact-free heart rate measurements that is automated, motion-tolerant.
2. capable of performing concomitant measurements on more than one person at a time.

3. AS-LMS method for MA reduction

M. Raghu Ram, K. Venu Madhav, E. Hari Krishna [16] proposed a simple and efficient approach based on adaptive step-size least mean squares (AS-LMS) adaptive filter for reducing MA in corrupted PPG signals in their IEEE transaction paper [may 2012].

Advantage:

1. No extra hardware is required for detecting noise.
2. A synthetic noise reference signal for an adaptive filtering process, representing MA noise, is generated internally from the MA-corrupted PPG signal itself.

III. IMPLEMENTATION DETAILS

There are three modules in this system like data collection, data preprocessing and parameter extraction.

Data Collection

The PPG video signals are recorded during this first phase. In this proposed system the PPG videos are recorded using Samsung ACE inbuilt camera of 5megapixel image clarity. Subsequent steps are followed.

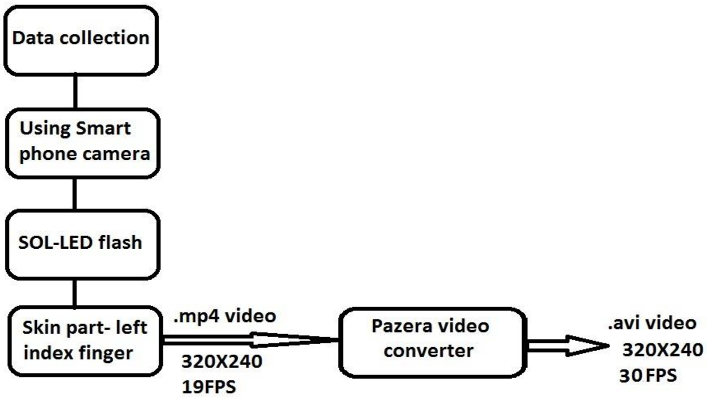

Fig 1 The avi videos are used for further processing.

Data Preprocessor

The noise can limit the accuracy of the final readings. Even the slightest movement of the subject can cause error in output. The motion artifact should be removed for better results. ICA algorithm is used for MA reduction and independent components are estimated. By using these independent components the MA reduced signal is estimated and used for further analysis.

Parameter Extraction

The frames are separated from .avi videos. Then RGB bands are separated. Only green band is used for HR and RR estimation as high absorption is observed at green band. Red and blue bands are used for oxygen saturation level estimation. The ROI selection is performed on green band video frames by removing higher amplitude data. The beat by beat interval is computed by observing the intensity changes. The number of peaks in the signal is estimated and the beats per minute is calculated as HR. The power spectral density is calculated by using Welch periodogram. Then RR is calculated by using this PSD signal.

RED and Blue Bands are used for oxygen saturation level monitoring. AC and DC components at green and blue bands are estimated which are used for final SpO2 percentage calculation.

IV. RESULT ANALYSIS

The final readings and the readings taken by using pulse oxymeter are compared. The 25 subjects are considered and the readings are compared with standard readings. The HR,RR and SpO2 values are displayed to the user. The following graph shows the comparison between standard readings and readings by our system.

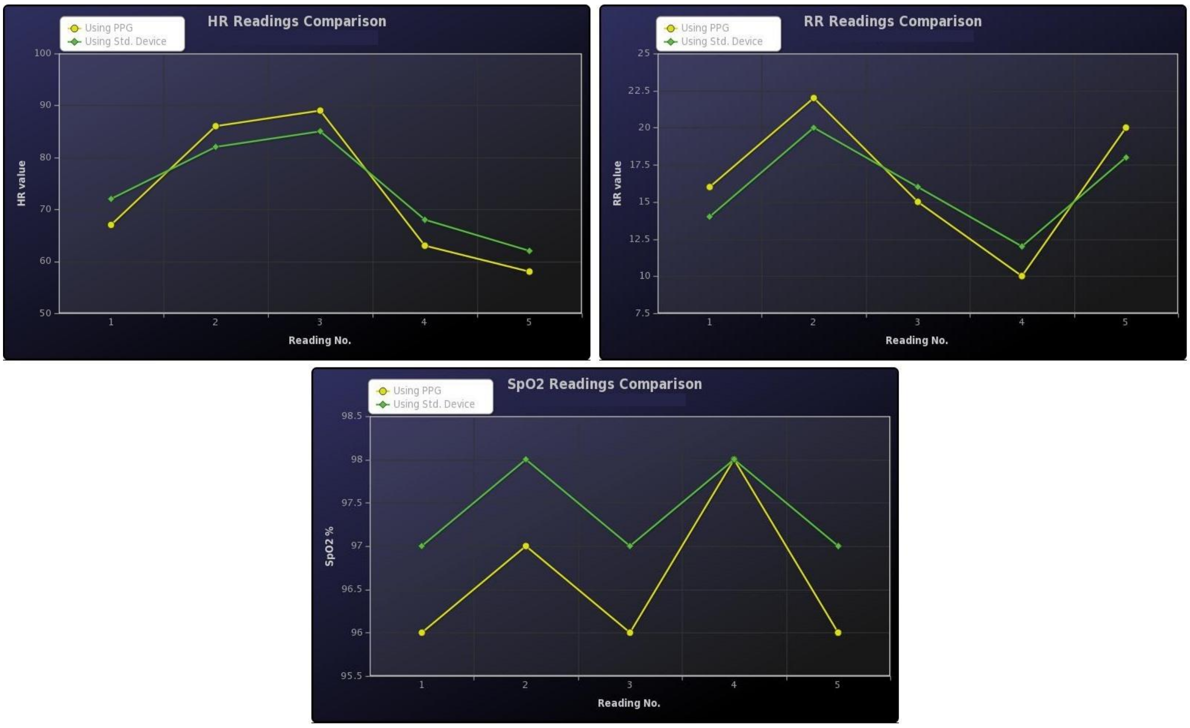

Fig 2 Result

V. CONCLUSION

In above paper, we used inbuilt camera of a smart phone The pulse oximeter has become one of the most common physiological monitors used in hospitals today. Moreover, algorithms have been reported to detect atrial fibrillation, blood loss, and autonomic nervous system disorders, in addition to traditional vital sign measurements of HR, respiration rate, and oxygen saturation from the dynamics in a pulse oximeter signal. The mobile phone cameras have the potential to monitor the pulsatile PPG signal. Current mobile phone technology extends beyond simply monitoring and measuring with ease for a patient; it could also be used to relay the information to medical professionals. This gives a patient the ability to carry an accurate physiological monitor anywhere, without additional hardware beyond what's already included in many consumer mobile phones.

The system readings were checked by using existing standard systems in presence of doctors and it is observed that in case of 98% cases, both the readings are within the same range. As per the doctor's advice, the system can be used for clinical as well as personal use.

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AUTHORS

Shruti Madan Kshirsagar received the Bachelor degree (B.Tech.) in Computer Science And engineering in 2011 from Walchand College Of Engineering, Sangli. She is now pursuing Master's degree in Computer Engineering at Vidya Pratishthan's College of Engineering, BARAMATI. Her current research interests include Biomedical engineering and signal processing.

Gyankamal Chhajed obtained Engineering degree (B.E.) in Computer Science and Engineering in the year 1991-95 from S.G.G.S.I.E.T, Nanded and Postgraduate degree (M.Tech.) in Computer Engineering from College of Engineering, Pune (COEP) in the year 2005-2007 . She is approved Undergraduate and Postgraduate teacher of Pune university and having about 17 yrs. of experience. She guided many projects at Undergraduate and Postgraduate Level. Gyankamal authored a book and has 14 publications at the national, international level for Conferences and Journal. She is life member of the ISTE & International Association IACSIT. Her research interests include Steganography and Watermarking, Image processing , Data mining and Information Retrieval , Biomedical Engineering.