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A Review of Photoplethysmography based Heart Rate and Blood Pressure Monitoring System

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Abstract*—Recent advances in wearable technologies have opened a new period in smart and connected healthcare bias to address the demanding requirements of the growing population in hospitals and specifically in home surroundings. Smart health monitoring system has great eventuality to reduce health care costs and to effectively use available coffers by reducing false admonitions as well as spare hospitalization events. Likewise, it can significantly enhance individualized health in the home terrain in terms of early discovery of life hanging events, nonstop complaint monitoring, assessment, and home recuperation. The standard vital sign covering systems are neither affordable nor accessible to be set up at home for individual health monitoring because of several prohibitive limitations similar as the need of a professional for data interpretation as well as the size, cost, and the conservation of sophisticated ministry. On the other hand, smart health monitoring bias can give important information about the vital signs including heart rate (HR), blood pressure (BP), and respiration rate (RR) at a much lower cost and with minimum estimation sweats with the help of remote Photoplethysmography (rPPG) technique. They can also give better dispatches for cases in remote areas similar that professionals can examine cases ever and give clinical consultations. The proposed frame uses the regular camera available in smart phone, tablet, and laptop bias to prize the vital signs without any redundant medical grade outfit or body detector. The proposed fashion directly excerpts the blood volume changes in the forepart region due to cardiovascular conditioning. A unique protocol designed to consider several real world influential factors while recording the videos validates the proposed approach for further rigorous test conditions. This review highlights research behind smart phone and video camera methods for measuring heart rate and BP. This study provides a review of the recent advances in remote healthcare and monitoring in both contactless methods. With the review, we discuss some issues available in most systems. The paper also includes some directions for future research.

Keywords— Remote Photoplethysmography (rPPG), Contactless methods, Heart rate, BP measurement,.

I. INTRODUCTION

What is a Photoplethysmograph?

Photoplethysmograph is a combination of the words photo and plethysmograph. A plethysmograph is a device that measures the volume of an organ, especially when it is expanding owing to changes in the air or blood within it. The term "photo" refers to it being done using light. The use of photoplethysmographs to monitor a patient's pulse is common. They are inexpensive due to their simplicity, as they only have three major components: an LED light source, a photodiode, and an amplifier. The light from the LED (or LEDs) is beamed into and through the skin of the patient before being detected by the photo-diode and converted back into an electrical signal (see Fig. 1). As the volume of blood within the patient's blood vessels fluctuates, light from the LED is absorbed and reflected in various proportions. It does so as part of their natural heartbeat rhythm. The amount of light detected by the photo-diode fluctuates as the blood volume under the sensor changes. A PPG is best worn on the finger and is ideally attached to the patient's extremities.

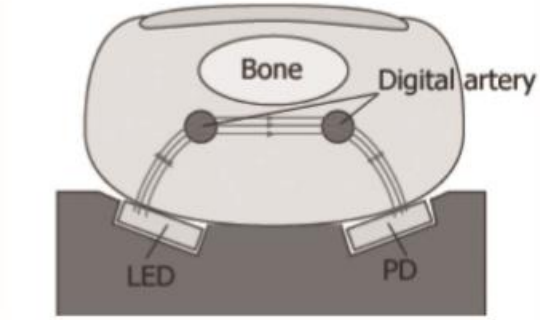

Fig 1. Photoplethysmograph - finger cross section [7]

Other places, such as the ear and two, are also appropriate. Pulse oximeters are another name for photoplethysmographs. The name refers to their present principal function of monitoring a patient's pulse, as well as the phenomena of fluctuating light absorption or reflection by blood arteries, which is caused by the amount of oxygen carried by the blood. A pulse oximeter, on the other hand, is a form of photoplethysmograph. A photoplethysmograph generates a photoplethysmogram, which is the device's output. Both the gadget and its output are commonly referred to as PPG. However, in this work, PPG refers to the photoplethysmograph, or gadget.

Photoplethysmography (PPG) is a non-invasive, optical technique that measures the blood volume variations in the living skin. The underlying phenomenon is that at every heartbeat the heart pumps blood into the vasculature , therefore its volume increases, which in turn results in more light absorption. In consequence, the absorption and scattering of light change synchronously with the cardiac-cycle which can be detected with a photodetector. Utilizing this, different physiological variables can be derived such as pulse rate, respiration rate or blood pressure variability. Another common

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technique with which we can detect cardiac events is electrocardiography (ECG) which measures the electrical activity of the heart and is considered to be the ground-truth for heart-rate measurement.

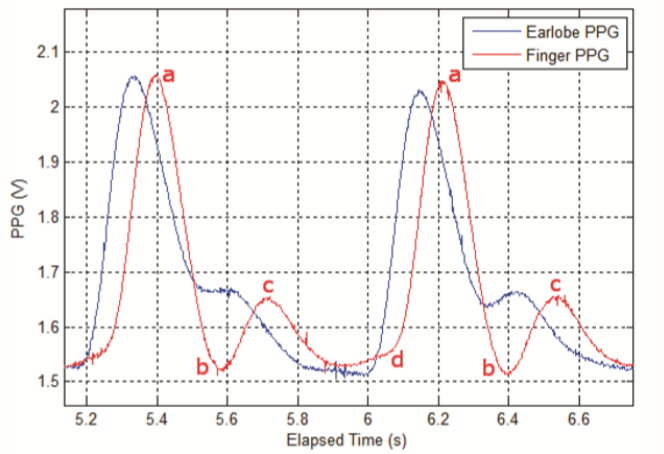

Fig 2. PPG signals on a photoplethysmogram (output) with critical spots on the red (finger) signal labelled a – d.

Despite the fact that it is widely used, cheap and reliable, the problem with ECG devices is that they are even more obtrusive than PPG devices: they require adhesive electrodes to be attached to the chest. This approach adapts non-contact health monitoring platform based on camera in order to overcome several limitations with the traditional electrode based health monitoring systems. In this study, we review the development of the field of rPPG since its emergence in 2008. The following are some of the important components of this waveform (see labels a–d in Fig. 2). 1. Systolic peak (a) 2. Diastolic peak (c) 3. Dichotic notch (b) 4. Systolic time (d – a) 5. Diastolic time (b – d) 6. Systolic slope (gradient from d – a)

This paper is organized as follows. Section II described the concept of remote patient monitoring through rPPG. In Section III future research direction and trends are described. In Section IV paper is concluded.

II. REMOTE PATIENT MONITORING THROUGH PHOTOPLETHYSMOGRAPHY

Remote patient monitoring systems are designed to gain a number of physiological data from cases. Most common data are Electrocardiogram (ECG), Electroencephalogram (EEG), heart beats and respiration rate, oxygen volume in blood or palpitation oximetry, signals from the nervous system, blood pressure, body/ skin temperature and blood glucose position. In addition to these, occasionally, weight of the case, position of exertion of the case and sleep data are collected. A number of inquiries have been done for crack operation and sleep monitoring operations.

Traditional systems collect data using detectors attached to the body. But these systems pose difficulty in terms of mobility for the case and a case's conditioning in diurnal living. Since this kind of bias influence case's comfort, sensitive physiological data get told. So the readings may not represent a case's factual illness but rather the discomfort a case, especially an senior case, is witnessing at the time a physiological reading is being taken. While there are numerous situations that invasive or with contact interventions are necessary, new exploration look into styles for carrying physiological data as non invasively as possible. For this end, contactless styles are being delved on considerably during the once many times. In this paper we bandy both with contact and contactless styles as both these types of systems are important for a experimenter in the field.

This section briefly discuss about remote patient monitoring through photoplethysmography.

In recent years, the field of remote photoplenthysmograph has emerged and advanced quickly to address the limitations of conventional and contact based methods. The involved research community is ever increasing and proposed several r-PPG algorithms [15] which aim to catch up with the traditional contact based systems regarding performance and reliability, so far unsuccessfully, but with promising results. A photoplethysmogram (PPG) is an optically attained plethysmogram that can be used to descry blood volume changes in the microvascular bed of towel [2]. Hertzman and Spealman [1] first observed in 1937 that the variation in light transmission of a finger could be detected by a photoelectric cell [1]. Having first been proposed in 1938, PPG is a fairly simple fashion that only relies on a light source to illuminate the skin towel, and a print sensor to measure the small variations in light intensity associated with changes in perfusion in the catchment volume [3]. The camera grounded health monitoring approach has been demonstrated in a variety of operation scripts, similar as ICUs, stressful work conditions, home terrain, and space disquisition (21). Ibrahim et.al. [19] demonstrated a eyeless source separation (BSS) grounded HR birth system from recorded videos. Photoplethysmography (PPG) is a fashion to measure blood volume changes in agreement with cardiac conditioning at some specific body locales, e.g., cutlet, earlobe, and face [20]. The PPG fashion has been reliably used in hospitals for SpO2 and HR measures. Recent studies on PPG have proved that PPG can be further used to cover BP [8], RR [19], and HRV [4] with suitable birth algorithms. The PPG fashion has been reliably used in hospitals for SpO2 and HR measures. Recent studies on PPG have proved that PPG can be further used to cover BP [14], RR [19], and HRV [20] with suitable birth algorithms. Two types of PPG technique are currently being in use namely: the transmission-mode PPG and the reflectance-mode PPG.

In 2010, the smart phone was used to obtain a photoplethysmogram signal for heart rate assessment by pressing the finger against the camera of phone [17]. A lot of important developments in the field such as contactless blood pressure meter, wrist watch based fall detection method and cane based fall detection system are reviewed in Patel et al.

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Year	Author	Work Done	Algorithm Used	Final Output
2016	Jain M et al. [**Error! Reference source not found.**1]	Estimating Heart Rate and Blood Pressure using facial video	- Pulse Transit Time -Principal Component Analysis	- Peak detection and Parameter Extraction - HR & BP Estimation
2017	M A Hassan et al. [1**Error! Reference source not found.**]	The heart rate and respiratory rate using an RGB camera and PPG signal	- Wavelet based Multivariate De-noising	- Remotely measuring the heart rate and respiratory rate from the PPG signal
2018	Tze-FAN Chao et al. [13]	Study of baseline and Atrial fibrillation	- Boundary parameters for heart related deceases	- Efficient and robust finding about baseline parameters for Heart beats
2018	Iman Sharifia et al. [14]	Dynamic model - pulse transit time (PTT) and photoplethysmogram intensity ratio (PIR), for the continuous cuffless BP estimation	- Multivariate adaptive regression - Spline Pulse transit Time - Taken's theorem	- Signal preprocessing, parameter extraction, state space reconstruction, and regression. The past dynamical state of the cardiopulmonary system is used to improve the accuracy of the estimation
2018	Norwahidah Ibrahim et al. [19]	A standard camera is able to detect illumination changes in the face skin due to the human cardiac pulse	- Temporal Photoplethysmograph (PPG) signal is extracted from the ROI - Independent Component Analysis (ICA) filter	- Non-invasive Video Based Heart Rate Monitoring System obtained from Various Distances of facial spots
2020	Tianming Zhao et al. [22]	Non-clinical PPG measurements and Authentication on Wrist-worn Wearables	- motion artifacts (MA) filtering - an adaptive classifier using the gradient boosting tree (GBT) method	- Developed a low-cost PPG-based continuous user authentication (CA) system, TrueHeart, using the wristworn wearable devices applications in low populated areas.
2020	T. Zhao et al.	developed a low-cost PPG-based continuous user authentication (CA) system	- the gradient boosting tree (GBT) method	identified general fiducial features and developed an adaptive classifier using
2021	Raposo A et al. [23]	cbPPG approaches provide simple, lowcost, and effective methods to remotely monitor patients' vital signs	BITalino PPG signal and manually setting the right camera parameters	Covering a light source and the camera sensor with a finger, it is possible to acquire the camera-based photoplethysmography (cbPPG) signal

[14]. Considering ECG as a reliable technique to monitor cardiac activity, PPG also represents similar characteristics for potential applications. A further compact and computationally more effective algorithm was proposed by Wang et al. named Full Videotape Palpitation birth (FVP) [8] that bypasses selection and shadowing, exercising the color features of the videotape. The author emphasized its felicity for long- term monitoring in cases when the background is constant. There are two introductory types of photoplethysmography transmittance and reflectance [9, 10]. Reflectance photoplethysmography has been used in this design. In reflectance photoplethysmography, a light source and a light detector are placed on the same side of a body part [7]. In a clinical setting, PPG is generally measured with a palpitation oximeter, generally clamped to a person's finger, and consists of a light source on the top and a photo sensor on the bottom. The detector also measures changes in light immersion, allowing it to distinguish between oxygenated and deoxygenated blood. A PPG detector used in immersion mode must be located on the body at a point where transmitted light can be detected [20]. Accordingly, dimension spots are limited to the extremities of the body, similar as the fingertips or earlobes. Bogdan et al. explains a system for remotely assessing heart rate by using skin color process. This process uses principal component analysis (PCA) and empirical mode decomposition (EMD) [9].

III. FUTURE OUTLOOK

We noticed that a set of factors greatly affect the adhesion of the signal. At first, we found that the warmth of the fingertip changes the quantity of blood flows, leading to slightly different measures. Secondly, breathing has an effect on the signal heart beats are stronger when inhaling compared to exhaling. We also plan to more understand the device capabilities demanded for this approach to be used successfully. Originally, assessing the hardware layout impact on the signal quality, in particular distance between light source and camera. Secondly, using lower frame rates and lower resolution recordings, as using more coarse-granulated measures will enable the use of PPG authentication on lower- end bias. Eventually, coming work includes the confirmation on a wide range of data including recording videos from a large number of subjects with different skin colors and different device operation conditioning. Future trials may antedate traditional image processing methods. Chen and McDuff (17) unfolded DeepPhys, a convolutional neural network, and applied it to videotape frames to retrieve the blood volume pulsation, measuring heart and breathe rate.

Overall, further studies need to be done to see the acceptance of these methodologies with the medical community and patients. Although some trial studies have been done, error correction methodologies in the technology haven't been capable to win the medical professionals' complete trust.

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IV. CONCLUSION

This paper has reviewed remote patient monitoring systems to efficiently measure heart rate and blood pressure. Most recent developments in remote photoplethysmography have been discussed here. This prevents unnecessary additional trips to doctors, provides daily information on changes in cardiovascular health, and may help detect signs leading to stroke or disease. Analysis of existing research has been presented here. The review shows that this technology making significant impact on the field of health monitoring system. Issues are also increased with the advancement of technology. Overall, smartphones and videotape cameras will give a more complete and preliminarily assessment of cardiovascular physiology, helping to prevent stroke and blood vessel- related diseases. The paper concludes with some suggestions for future research in the field of rPPG and remote health monitoring system.

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