



Analysis of vital signs using remote photoplethysmography (RPPG)

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Abstract

In health care applications, an evolution of electronics has made drastic advancements. There are some problems created due to this advancement. To estimate the coronary heart rate, till date some problems have been confronted. To overcome these issues, remote photoplethysmography (RPPG) technology is used to determine the heart rate (HR) and respiratory rate (RR) by using normal web cameras, without any additional hardware. Here, a high resolution camera detects the face using a face detector by means of image processing techniques. Hardware part is only used to display the heart rate and respiratory rate using sensors. The performance analysis demonstrates the practicality of the patients. Experimental results of heart rate measurement show that the proposed dynamic ROI method for RPPG can effectively improve the RPPG signal quality, compared with the state-of-the-art ROI methods for RPPG. Objective performance tests show strong correlation with the ground truth values for the estimated heart rate and variation.

Keywords Photoplethysmography (PPG) · Heart rate · Respiratory rate · Remote photoplethysmography

1 Introduction

The developing stride about the liveliness of human being has step up the importance of the impact regarding unbalanced and emotional overload of the physical, mental and social environment. In the present scenario, Indian rural healthcare faces the crisis on peerless to any other social sector. Approximately 80% of the medical visits in India are by ruralites. Still, the majority of them set out about 90 km to avail the health facilities of which 70–80% is born out of packet landing them in poverty (Alafeef and Fraiwan 2020). Government succeeded in implementing infrastructures in urban areas but fail to do so in rural, which endorse 70% of

the population. Though existing infrastructures and technology set up providing health care for rural India are in an organized way, but the qualitative and quantitative way of primary health care facilities are far less than the given measures of (WHO), this creates various insufficient health care services and also this leads to more inconvenience for the ruralites to set out for urban areas more often. This can be overcome by the advanced technologies in Medical Health Science (Alhammad 2018). There are several ways for detecting heart rate, pulse as well as respiratory rate of human body system. The clinical practices for the computation of heart rate and pulse rate are done by ECG (electrocardiogram) and estimation of respiratory rate are done by acoustic based method or radar-based respiration rate monitoring.

Photoplethysmography (PPG) is the advanced technology in Medical Health Science. Which identifies the optical assimilation changes in human skin epidermis and it is more prominent. PPG can also be used to assess the blood volume variation reverted to heartbeat and they are appropriate for monitoring heart rate, pulse rate, and respiratory rate (Malacarne et al. 2016).

The process of functioning on remote photoplethysmography has been vast, in some tries the RPPG (Alsulami et al. 2021) has been wont to notice only the heart beat using face video extraction, and processing (Noulas and Krose 2006).

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But in this method, the combinations and accuracy of the information may lead to the compensated error sources. In certain cases, the RPPG has been used to estimate the average heart rate and variability measurement which doesn't provide a clear analysis on heart rate estimation (Noulas and Krose 2006). This is overcome by face detectors but it may also have an impact on results when poor lighting conditions occur.

To overcome the above-pointed issues we come up with an innovative method "Measurement of Vital signs using RPPG" (Haan and Leest 2014). Our proposed method is to compute the pulse, respiratory and heart rate using remote PPG. RPPG signal consists of many components, the major functional blocks of RPPG signal is back scattered radiation from the human epidermis (Gil et al. 2010). It is a low cost and non-contact method of measurements through the blood-volume-pulse (BVP) for computation of HR, RR and heart variable rate (HR). We developed this method for the automated estimation of physiological signs. By recording a facial video through webcam, the sensors enumerate combinations of the reflected signal of photoplethysmography (RPPG) (Attaoui et al. 2020). To automatically detect the coordinates of face location is processed by region of interest (ROI). The region of interest is separated into three RGB channels. Analysis of HRV is realized by power-spectral density assessment using 'Lomb' periodogram. The both frequency components are evaluated under the equivalent power spectral density (PSD) curve (Fan et al. 2020).

1.1 Related work

Earlier findings portrayed a framework with a system shows the face videos. They have estimated the heart rate. The main work in the system was identified the face video sequence and compute the extraction and processing of a time signal (Feng et al. 2014) by which the heart-rate is estimated. This provides the temporal colour changes analysis from the study of blood volume occurs in video patches.

In past work, the facial regions with adaptive PPG measurements show the vital signs. In this system facial reader tracks the facial land mark hence; this method of face reader is robust (Emrah Talsi et al. 2014). Active appearance model (AAM) technique is used to identify the facial landmark by means of free head movement. This method exclaims about RPPG evaluation techniques are analyzed for monitoring the important signs of the human body.

A proposed approach explained the relationship about the characterization of the heart-rate analysis using a web camera. By means of digital signal processing we can analyze the heart rate as well as blood flow for all the age groups. The video could be magnified by Eulerian method (Allen 2007). In learning based detection techniques (heart rate) achieved by RPPG based techniques are explained. Human

heart rate variability study described the attacks on heart beat based security using remote photoplethysmography (Carvalho et al. 2014). This paper is used to evaluate the feasibility of attacking on Heart Beat Based Security (HBBS) systems through measuring heart beats remotely through RPPG. The time interval between successive heart beats cardiac inter pulse interval (CIPI) is unique feature which is used to enumerate the security in mobile health (Lempe et al. 2013). Heart rate variability estimation in Photoplethysmography signal is discussed earlier using Bayesian learning approach. In this attempt the noise is characterized mathematically which is identified from PPG signals collected by wearable sensors (Lin et al. 2021) This is a probabilistic advent, analyzed on Bayesian learning approach, to better detect the HRV and PPG signal which is observed through wearable device and embellish the performance of the automatic multi scale peak detection used to analyze the peak detection (Purtov et al. 2016).

Organization: The remainder of the paper is structured as follows. Preliminaries are introduced in Sect. 2. Methodology is given in Sect. 3. Section 4 gives the detailed experimental Analysis. Section 5 provides the conclusion.

2 Preliminaries

Photoplethysmography is a measurement technique that can be used to detect changes in blood volume in the microvascular region of tissue (Makhlouf et al. 2019). Introducing new technologies includes PPG imaging technology, telemedicine, and remote monitoring, (McDuff et al. 2015), and (Nkurikiyeyezu et al. 2018) evaluate models of a near-infrared CCD PPG imaging model for flow the blood and other events in the noise. The purpose of this technology is to provide new information about the physical activity of the whole body and to detect changes associated with ulcer formation and wound healing. In 2005, Wieringa et al. described the non-contact wavelength PPG modeling program as its first application of the long-distance model of arterial oxygen saturation (SpO_2) distributed machines. The system obtains a two-dimensional matrix PPG image signal that is spatially resolved at three wavelengths (660 nm, 810 nm, and 940 nm) during breath changes. Oxygen intake can be useful in many areas of medicine, for example to measure the immune system. PPG has great potential for telemedicine, including home/remote medical checkups. Miniaturization, ease of use and durability are key requirements for him system. This is reflected in the light-based PPG sensors to monitor muscle pulse-to-pulse (Seepers et al. 2017), and the need for reduced muscle tone, better organized space and reduced power consumption. Added in-house PPG sensors and in -house health monitor to be able to

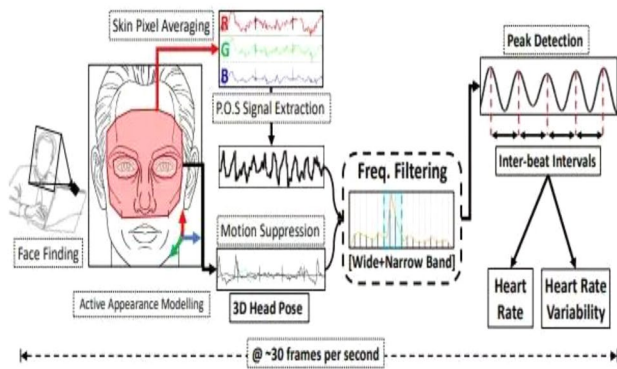


Fig. 1 The block diagram of the heart rate and heart rate variability estimation pipeline

measure oxygen and oxygen uptake from visual surfaces at different frames 805, 904 and 975 nm) (Rouast et al. 2018).

The face in captured webcam images is detected and modeled to track the skin pixels in the region of interest. The average value of RGB signals is extracted over time. In parallel, the head movements are tracked and used to suppress motion noise Singh and Badaya (2014). The process of filtering the wide and narrow band signals produces a clean pulse waveform from which peaks are detected. The Fig. 1 shows functional blocks of heart Rate and heart rate variability. The inter-beat intervals obtained from these peaks are then used to compute heart rate and heart rate variability. The full analysis can be performed in real time on a computer Shekar et al. (2020).

3 Proposed methodology

Remote Photoplethysmography enables contactless screening of mankind's cardiovascular exercises by identifying the pulse-induced subtle colour variation on human skin surface utilizing a multi-wavelength RGB camera. The processes involved are recording a video of the test participant for a certain duration. Different from the conventional contact oximeter, this is done by using a web camera we can trace by using a detector other than any additional light source, it captures through a small lens using a CMOS image sensor.

The video is analyzed using an image processing technique such as image sensing and face detection techniques used to organize the entire face rectangle as region of interest (ROI). Then the mean-value of region of interest (ROI) on RGB channels for the frames is computed, this step removes the background noises. In the photoplethysmography technology when an incident light gets penetrated through the human-skin the adsorption of light by lots of tissues remains the same. A variation is observed in the oxygenated arterial

blood. The reflection of each skin pixel is recorded in the video.

Figure 2 is a RPPG wave collected from a 5×5 pixels region on the subject's cheeks, which is a normal RPPG signal.

The alternative of observing a patient's physiological signs through a non-contact as well as remote implies has guarantee for enhancing access to and upgrading the conveyance of essential human care. Right now, proposed answers for non-contact estimation of key signs, for example, laser Doppler, heart and respiratory rate with thermal imaging as well as microwave radar. Non-contact assessment of heart rate (HR) variability, an autonomic activity, presents a greater challenge is also done.

Regardless of these great progressions, a typical downside of the previously mentioned proposition is that the frameworks are costly and require specialized hardware. Though the variation in the reflected light rays, photoplethysmography is used for sensing by means of low-cost and non-invasive cardiovascular blood volume pressure (BVP). Despite the fact that photoplethysmography is achieved by means of dedicated light sources.

With the illumination source, the coloured version is also available in the online normal ambient. The performance characteristics are validated by minimal raw images with heuristic interpretation computed by physiological and mathematical models. Nowadays, human faces can be extracted from digital color video recordings using the HR method. The various physiological parameters are used to propose in this paper. Importantly, we could take blood volume pressure for manipulate the HRV and HR. From my observation the cheapest method achieved for HRV measurements.

The Blood volume pressure is the very basic and vital source which is used to propagate to all parts of the body. The timing of CV movement changes could be monitored by path length changes of facial blood vessels in the cardiac cycle. The reflected plethysmographic signals are achieved by recording a video of the facial region with a webcam, the red, green, and blue (RGB) color sensors pick up a mixture of sources of fluctuations in light.

Each and every colour sensor holds the original message signals with various weights, gives the hemoglobin adsorption compared with the visible and IR spectral range. The

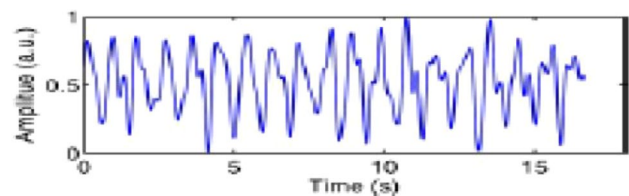


Fig. 2 Typical Remote Photoplethysmography (RPPG) waveform

received output signals in the color sensors RGB denote $y_1(t)$, $y_2(t)$, and $y_3(t)$, respectively; it shows the recorded signal with amplitudes of time period t . From the considerations, the input signals are shown by $x_1(t)$, $x_2(t)$, and $x_3(t)$.

3.1 Methods

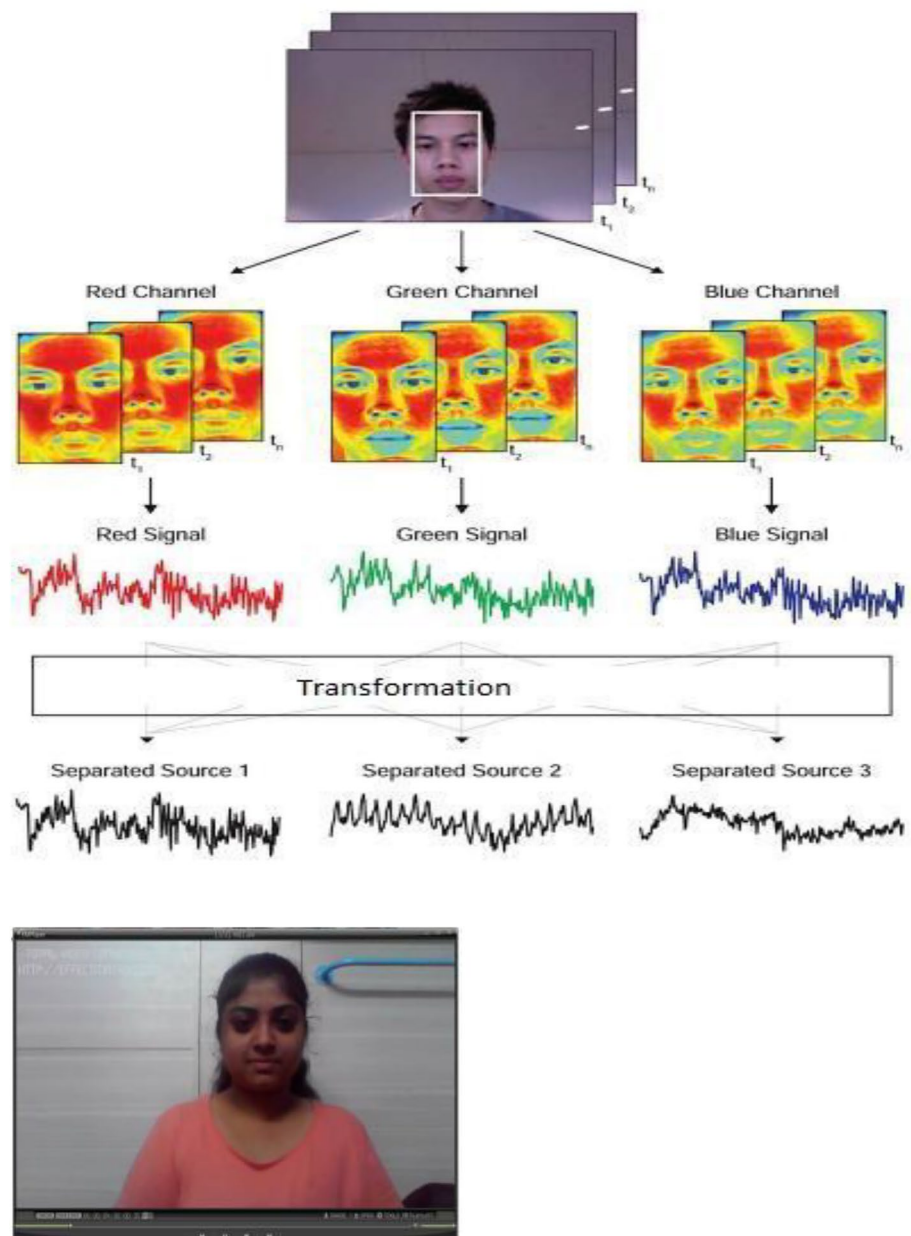
The results have been taken from the source of sunlight through the window while using an indoor unit. The basic sample signals shown in Fig. 3. The user was looking in front of a laptop at a distance of approx. 0.5 m from the built-in webcam. The person has to record a one minute video to keep breathing continuously and monitor facial actions.

The videos are saved in the AVI format in a laptop with the following color (24-bit RGB with three channels \times 8 bits/channel) at 16 frames per second (fps) with pixel resolution of 720×560 .

3.2 Remote PPG imaging

Current PPGi research often focuses on improving previous work by considering one or more image factors such as the movement of the subject, ambient light and the spectral sensitivity of the image sensor. Each of the other factors poses particular challenges in restoring accurate physiological data using any method specified.

Fig. 3 Sample video signals for face detection



3.2.1 Movement tolerance

The effect of object motion is one of the most studied dynamic performances in PPGi measurement. PPGi's early research focused on rigid and immobile areas of interest. Other studies have examined the algorithm's performance in limited motion translation using techniques such as simple object tracking with a focus on ROI (Allen 2007) and chromium-based or chromium-based signals from the RGB color space (Hsu et al. 2014). Approaches to assessing the contribution of motion artifacts and correcting PPGi signals using adaptive filtering have also been studied by Zanetti et al. (2021).

3.2.2 Image optimization

The functions of a thermal imager or image sensor that provide a reliable PPGi are not easy to understand given the different computational properties of the image sensor. These features include, but are not limited to, basic sensor types (such as CCD, CMOS, and other custom patterns), set of color filters (such as Bayer, Foveon X3, and RGBE), bit depth, image size, and pixel count. The overall image quality, which is not always related to the image sensor itself, such as the type and quality of the lens, the spectral characteristics of the light source and the aperture/shutter speed/ISO, also affects the overall content of the captured image.

3.2.3 Optimize areas of interest

The identification of areas of interest for PPGi measurements has been used to mark appropriate patient tissue (e.g., Thanga Selvi and Muthulakshmi (2020), Tsouri et al. (2012), Brown et al. (1993)) and background signals (e.g. Uthaya Kumar and Kamalraj (2020)). In a rather static, immobile person, the amplitude of the pulse waveform (indexed by the strength of the pulse frequency band in the frequency domain) can be compared with the small area of the mapped network. The spatial location with the largest pulse amplitude is the location that has the largest total contribution to the PPGi waveform. Hsu et al. (2014) demonstrated this technique and found that the most prominent facial areas for PPGi measurement were the carotid artery (in the neck), the infraorbital area and the central forehead above the nose.

3.3 Retrieval of BVP from video recordings

After analyzing the physiological recordings in MATLAB (Fan et al. 2020). From the web camera video recordings, we have analyzed the favorable BVP approach and its stages. The video recordings identified from the face locations

coordinate systems. The region of interest places a vital role with the mentioned 60% width and full height of the box calculations.

Each frame yields three different colors: red, green, blue measures the ROI with the raw signals with spatial average $y_1(t)$, $y_2(t)$, and $y_3(t)$, respectively. The one minute length is the measurable trace. The smoothness priors approach with various smoothing parameters $\lambda = 10$ and normalized as follows. The artifact with the motion removal used to split the fluctuations caused predominantly by the Blood volume pressure from the measured raw signals.

The hamming window with the splitter source signal using a 5 point moving average filter and BP filtered (128-point Hamming window, 0.7–4 Hz). The cubic spline function is achieved by means of sampling frequency with fine tuning of BVP peak fiducially point with 256 Hz. We have created a well-equipped algorithm to identify the BVP peaks in an interpolated signal and applied it to obtain the inter-beat intervals (IBIs). The tolerance of IBIs is achieved by a deferrable threshold algorithm to avoid the artifacts with an ectopic beat or motion consisting of 30%. The time series of 60/IBI with the mean computed by HR.

The Lomb periodogram techniques have been performed by the power spectral analysis of HRV methods. The power spectral density curve are 0.04–0.15 and 0.15–0.4 Hz, it consists of both low and high frequency combinations and measured in normalized units (n.u.) to mitigate the impacts in total power.

The baro reflex activity is achieved by the low frequency component including parasympathetic influences. The high frequency components are connected to respiratory sinus arrhythmia and parasympathetic influence IBI fluctuations that are in phase with exhalation and inhalation. From the sympathetic modulation, we have computed the mirror sympatho/vagal balance.

The HRV spectrum used to estimate the breathing and RR using high frequency components. The respiratory rate (RR) with respect to high frequency peaks shows the frequency of respiratory changes (Feng et al. 2014). Thus, f_{HFpeak} in the HRV PSD is measured from the web camera recordings as 60/ f_{HF} peak. The power spectral density achieved using the chest belt sensor was measured by the frequency to the dominant peak f_{resp} peak in the power spectral density of the recorded respiratory waveform using 60/ f_{resp} peak.

4 Experimental results

The Arduino platform allows easy and fast prototyping. Which is able to hook up the LCD and be able to display messages, the input is an analog input in the Arduino platform. The basic control circuit and sensor circuit used to measure the heartbeat with IR LED with photo-diode

additionally other components to connect the signal to a microcontroller. The light signal detected from the light varies with IR LED finger pulse from which blood counts the heartbeat.

When the heartbeat occurs the blood is pumped through all parts of the human and it will be converted to capillary tissues. As heartbeat increases the capillary tissues volume also increases. The pulse rate can be measured by light present in the sensor module. In the capillary blood vessels light reflection was analyzed by means of volume of blood. A pulse generated from the sensor shows the changes in light transmission.

The respiratory rate is sensed through the vagal operation of the human body, which sense the amount of inhaling and exhaling of the human to analyze the RR. While we compared the average going up and down by the person breathing in and out (inhaling and exhaling) which completes one cycle, this is analyzed through sensor.

The above Table 1 provides the comparative analysis of Heart rate and Respiratory Rate (in terms of RPPG and Hardware measurements). Here, the illustrations are made by means of 10 patients. The sample of ten patients gives different heart rate (HR) as well as Respiratory rate (RR). The detailed investigations on RPPG and hardware measurements shows the clear idea in the Fig. 4a and b.

The brief survey has been taken from various Medical Colleges across southern region of Tamil Nadu, India, The above statistical data received from Madurai Government Rajaji Hospital (GRH, Madurai), Christian Mission Hospital and Research Institute (CMHRI), Stanley medical college hospital (SMCH) and Meenakshi Mission Hospital (MMH, Madurai). The overall statistical data analyzed and represented in the above Table 1.

The overall graph in the Fig. 4a and b shows the total number of sample patients vs. heart rate and respiratory rate. Here, various patients heart rate and the respiratory rate also

Table 1 The heart rate values obtained by using RPPG and Hardware measurement

Name	Heart rate		Respiratory rate	
	RPPG	Hardware	RPPG	Hardware
Patient 1	62	57	15	18
Patient 2	60	60	20	24
Patient 3	65	72	20	24
Patient 4	68	68	26.6	28
Patient 5	63	55	17	21
Patient 6	61	64	19	22
Patient 7	63	72	24	27
Patient 8	67	68	23	21
Patient 9	62	57	17	20
Patient 10	60	63	21	22

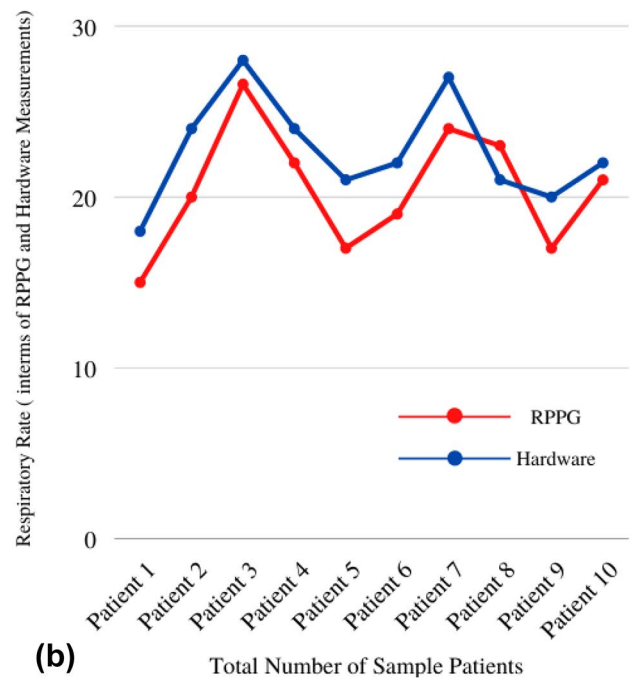
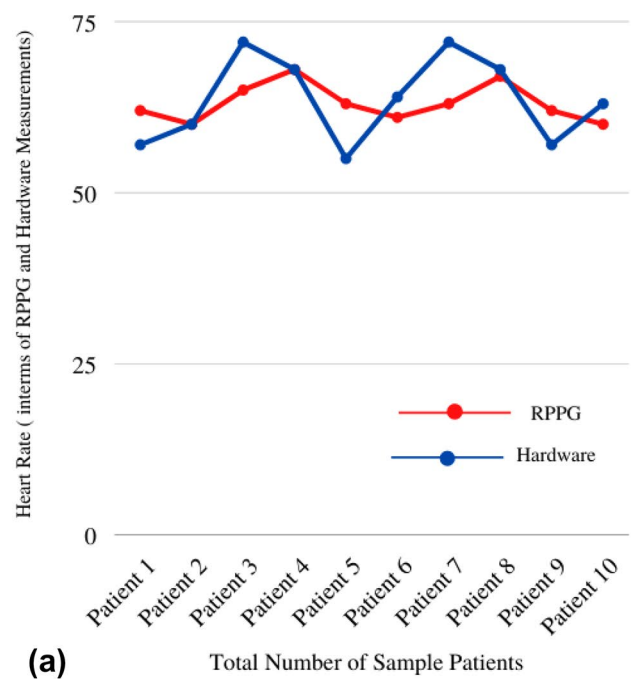


Fig. 4 **a** Total number of sample patients Vs. Heart rate. **b** Total number of sample patients Vs. Respiratory rate

been analyzed. The RPPG and the hardware measurements of both heart rate and respiratory rate shows practically in the above figures. The red marked lines are indicating RPPG values and Blue marked lines indicating that Hardware measurements.

5 Conclusion

Hence, from the multiple physiological parameters measure the feasibility of a web camera. The main objective of this work is to achieve automatic cardiac function using HRV which also includes respiratory rate (RR) and heart rate (HR). The important signs measure from the blood volume pressure (BVP) waveform and resultant values with access to spectral components with an average time of 60 beats in the 2–3 min recorded videos. Using standard PC for an image acquisition with a sampling rate may be fluctuated by 15 fps and also it causes the misalignment of the BVP peaks compared to the reference signal. If we change the pulse transit time, photoplethysmography (PPG) is affected by the variation to the arterial compliance and blood pressure, but it has been shown to be a good surrogate of HRV at rest. Since the proposed method for RPPG is able to vary the ROI along with the subject's physical variation and the environmental variation, we believe that this proposed method can enhance the adaptability of the RPPG in practice. Moreover, the effect of heart rate variability could further be analyzed for evaluating physical and psychological experiments. The purpose of this study was to build up knowledge about the constraints and limitations of measuring HR and HRV accurately by RPPG, which would provide guidelines for preparing the camera settings and shooting environment. In our future work, we will extend it to support big data auditing using Internet of Things (IoT) technologies.

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