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# Contact and Non-Contact methods of Photo Plethysmography

**Deepakfranklin P, Krishnamoorthi M, Kalamani M**

***Abstract - Today there are several equipment to measure various physiological parameters of human, some of them are compact and most of them are huge. In order to monitor a person's health properly it is not adequate to measure the physiological parameter in laboratory alone, it has to be in regular basis for a considerable duration. One of the most preferred and desirable technique is photo plethysmography (PPG). Plethysmography is a volumetric measurement of organ. In PPG the signal recorded is obtained by the information carried by the light that is either reflected or passes through the veins, the light intensity may vary depending on the blood volume. It is a non-invasive method and gives information on cardiac vascular system. This survey specially focuses on various parameters that can be derived from PPG, methods to detect these parameters from PPG and possible techniques used to measure PPG. Discussion will also throw some light on difficulties, disadvantages and future enhancements that are in photo plethysmography. A vast collection of sample data is necessary to give a result on the parameters obtained from PPG which are provided by various websites.***

***Keywords: photo plethysmography, blood volume, physiological parameters, infrared light, artery, cardiac vascular system, ambient light.***

## I. INTRODUCTION

There are several researches going on in the field of biomedical signal processing among them one of the most important is monitoring photo plethysmography and obtaining various parameters from it. Photo Plethysmography (PPG) is a technique to obtain information on cardiac vascular system from the blood volume variation in the veins.The device used contains just an infrared light or a normal light source which will be the source. Light rays either passes through or gets reflected from the tissue surface, while falling on these tissues depending on their thickness and density the light gets absorbed and remaining light is let to pass or reflected. The detector on same side of source or on opposite side will pick up these light rays and information is obtained. When the detectors and source are on same side it is called reflectance PPG as the light rays acquired are reflected from the tissues. If the source and detector are on opposite side of veins it is said to be transmission PPG. The probe structure used for measuring PPG in transmission mode is shown in figure 1. Among these reflectance PPG is most preferred because it is simple and advantageous to detect weak signals in PPG [1-2].

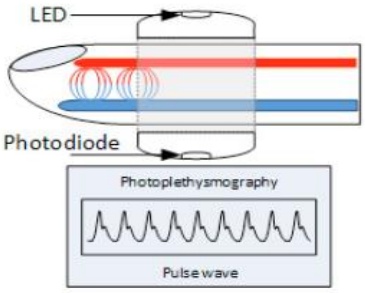


**Fig 1. PPG probe in Transmission Mode [3-4].**

The figure 2 shows the reflectance type probe to measure PPG signal.

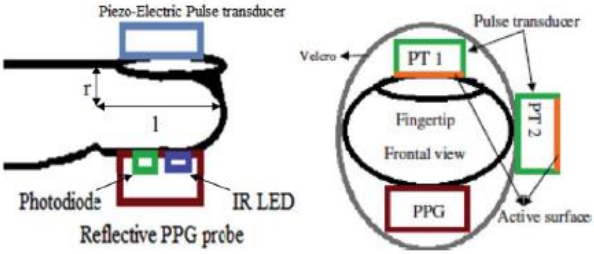


**Fig 2. PPG probe in Reflectance Mode [5].**

The non-invasive techniques for measuring parameters related to cardiac system is preferred over invasive techniques, PPG is one such technique. The PPG signal has two components AC component and DC component. AC component of the signal is influenced by cardiac synchronous changes in blood volume with heart beat. DC component of the signal is large and influenced by respiration, sympathetic nervous system activity and thermoregulation [6]. PPG can be measured either through devices in contact or by remote method. A number of new methods are being presented in remote monitoring of PPG using digital cameras and image processing. In PPG imaging a dedicated light source is used for illuminating the subject, mostly hands or face of the subject is captured and used for measuring blood volume pulse (BVP).

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From this BVP physiological parameters can be derived through several processing techniques. Figure 3 shows the process involved in obtaining PPG signal by imaging.

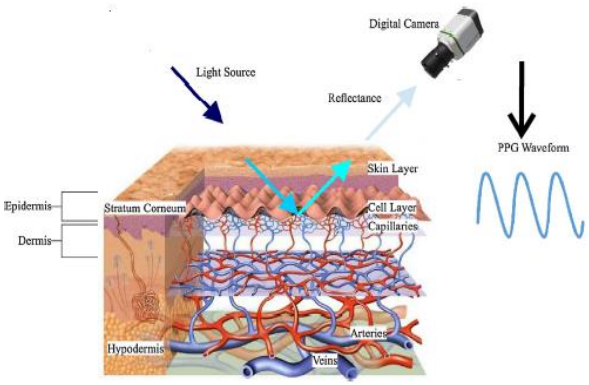


**Fig 3. Non-Contact PPG imaging technique [7].**

## II. PHOTO PLETHYSMOGRAPH USING CONTACT METHOD

The advancement in the field of health care has given rise to various new measuring devices that are compact and effective in monitoring at low power. These devices are cheaper and affordable by many people, it also helps in emergency cases of old aged people whom are helpless at such situations.

In this study the focus will be on Non-invasive photo plethysmography traditional contact device. When a person is not feeling well the first and fore most thing doctor does is counting the pulse in wrist, it gives information on the cardio pulmonary function. PPG sensor produces the waveform which carries details of heart rate, oxygen level in hemoglobin and blood pressure [8]. All these parameters are obtained from AC component of the PPG signal. Other possible parameters are body temperature, respiration rate and activity of sympathetic nervous system. The frequency range of AC component of PPG signal is greater than 0.6 Hz and low frequency, DC components are less than 0.6 Hz.

### A. PPG Contact Device

The basic elements of PPG sensor device are light source, photo detector and amplifier. Light source can be red, blue, green or infrared. Blue light has a wavelength of 450nm, it can penetrate epidermis. Green light of wavelength 510nm can penetrate into dermis layer. Green LED's are absorbed greatly by hemoglobin and provides much variation in intensity which is highly suitable for pulse rate measuring. Red light of wavelength 660nm penetrates close to fatty tissue. Infrared light of wavelength 905nm can penetrate beyond fatty tissues. Earlier stages PPG sensor were using Red or Infrared LED's whereas recent cases exploit Green LED. Figure 3 shows the different penetration depths of lights with different wavelength [9].

Photodetector is usually a photodiode whose output is current. The current varies with the intensity of the incident light.As the reflectance mode is preferred both photodetector and light source lie on same side which may introduce crosstalk problems due to refraction of light, this is minimized by choosing flat package of LED and Photodiode [2-3].

Fig 3. Lights of varying wavelength and its different penetration depth[6],[10].

For signal processing current variation cannot be considered hence Transimpedance Amplifier is used to bring about the variation in voltage with respect to change in current which in turn depends on intensity of light. Figure 4 shows the simple circuitry for Transimpedance amplifier [11].

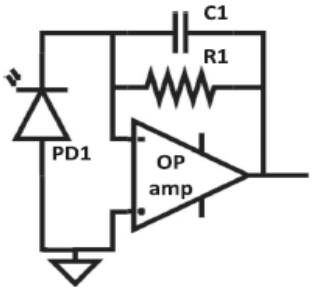


**Fig 4. Transimpedance Amplifier [6]**

Analog Filters can be used to filter out unwanted noise at initial stage of PPG signal, before processing it to extract various information and also to obtain AC and DC components as required for measuring desired physiological parameters [6].

### B. Physiological parameters

Let's see the possible parameters that can be obtained from the PPG signal. Heart rate is foremost vital parameters that can be derived from AC component of PPG signal. Oxygen Saturation level in blood can be measured, hence this sensor is also known as pulse oximeter. Blood Pressure can be obtained from the AC component of PPG signal. Respiration rate can be obtained from DC component of PPG Signal. Temperature has impact on PPG signal hence body temperature can be obtained. Increase in temperature affects the quality of PPG[4]. Depression in a person can also be monitored from PPG signal. As said in Ayurvedic medicine Pitta, Vadam and Kabam can also be measured using PPG signal which is not proved. Conscious level of the patient during general anesthesia can also be measured using the PPG signal. The level of oxyhemoglobin, deoxyhemoglobin and total hemoglobin can be measured and assessment of blood perfusion can be made [12], [1].

### C. Positioning of PPG device

The PPG device should be placed where the veins and arteries can be sensed for proper measurement of pulse rate variability. Early the PPG signal was measured from the rabbitear as study, then the same group of scientists were able to identify that the signal can also be obtained from finger [1].The femoral arteries in the thighs are also suitable to monitor PPG signal, in such cases the sensor device is not fixed to body instead to an object on which the subject has to sit. Reflectance type PPG measuring devices can only be used to monitor femoral arteries in thighs. The radial arteries


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near wrist are also suitable for monitoring PPG from wrist. Several devices are tied around wrist for obtaining quality PPG signal. The sensor probe can also be positioned in the toe to pick up PPG signal [1]. The device should be held in position, both in transmission and reflectance mode for proper measuring of PPG signal. The PPG signal obtained from fingers always has much higher amplitude [1]. Hence for most of the cases the monitoring probe is positioned in finger, where both reflectance type and transmission type can be used. Figure 5 shows the locations where probe can be placed. Figure 6 shows the sample signals measured from ear lobes, fingers and toes.

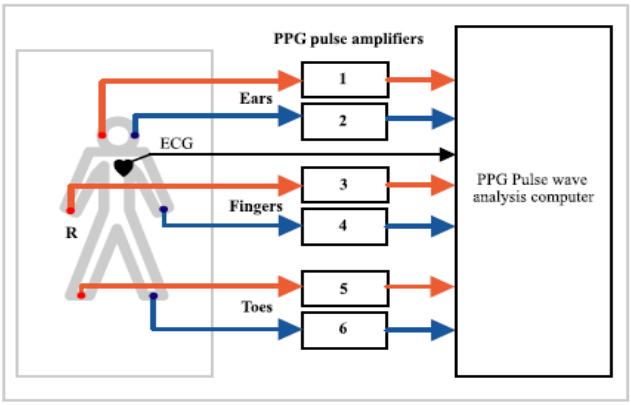


**Fig 5. Locations where the PPG probes can be placed [1].**

### D. Difficulties in Contact Method

The process of reproducing the measured physiological signal is very vital. There are several issues that affects the reproduction of the PPG signal by the sensor device such as method that is adopted either transmission or reflectance, the contact pressure that exists between device and the tissue, motion artifacts, tissue deformation, spot measurement, bandwidth of amplifier, posture of the person whose physiological parameters are measured, room temperature. The pressure between the tissue and sensor device should be maintained at a required rate, the signal quality will deteriorate if the pressure is high or low. No clinical standards have been established for measuring PPG signal [1], [13-16].

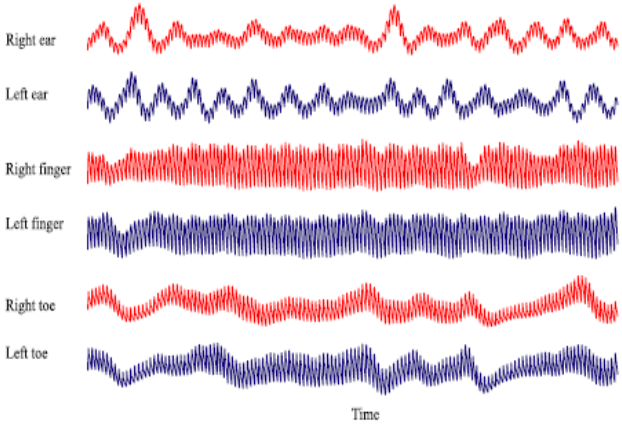


**Fig 6. Sample readings obtained from earlobes, finger and toe region [1]**

### E. Characteristics of PPG Signal

The PPG has two important characteristics of AC waveform. The first part is rising section called anacrotic phase and it is due to systole. The second phase is falling part called catacrotic phase and it is due to diastole and some impact from periphery. The features that can be extracted from PPG signal are beat to beat rise time, pulse transit time (PTT), amplitude and shape with variations for different cases. After normalization pulse width and height can also be considered. The pulse wave travels between sites of arteries within pulse transit time which is convenient to compute from which pulse wave velocity can be calculated. The Pulse transit time is inversely proportional to pulse wave velocity [17].

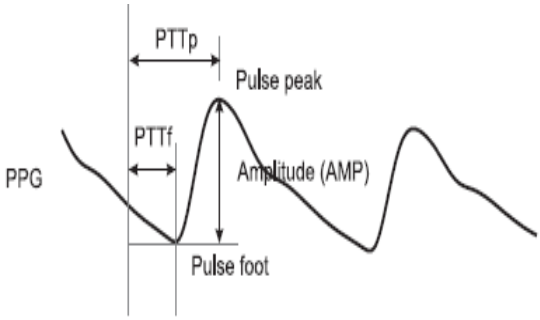


**Fig 7. PPG signal Characteristics**

The AC component of the PPG Signal is pulsatile and its frequency may vary from 1 to 1.4 Hz. He AC component sits on a large DC Components whose variation are very slow. The AC Component is mainly due to heart rate and DC component depends on respiration, vasomotor activity, thermoregulation and other circulatory activities that are slow. The PPG signal and its components are not understood completely, but it is accepted that there is valuable information in it which predicts the condition of cardiac vascular system [18], [13].

### F. PPG Signal processing

PPG signal can be analyzed by various methods such as time delay reconstruction method, Poincare method, Spectral analysis method, Machine learning, Wayland test, deterministic non-linear prediction, surrogation, time-frequency domain approach, Artificial neural network, wavelet spectrogram analysis, principal component analysis, Empirical Mode decomposition, Generic Algorithm, Bland-Altman method [19], joint sparse signal reconstruction and spectral fusion. Required features can be extracted from the PPG signal using any of the above-mentioned techniques. Compression of PPG signal is also possible [9], [20-26].

## III. PHOTO PLETHYSMOGRAPH USING NON-CONTACT METHOD

The photo plethysmography imaging (PPGi) is a recent development in photo plethysmography technique.The imaging method which is non-contact method overcomes most of the difficulties faced in traditional contact method of PPG. The motion artifact and problems due to interaction of light with tissue are overcome by the PPGi technique. In this method the subject's image is capture using one or more


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cameras in presence of ambient light and subjected to feature extraction. Theimages are segmented and information is extracted. The skin absorbs light in different ration hence there will be certain change in absorption, this change in skin color is due to blood volume change in arteries and veins. The main concept behind this method is absorption of light by blood is more compared to the tissues around it. PPG imaging visualizes dermal blood vessels and perfusion in various region of skin. The principle of PPGi is to illuminate the subject or a specific area in body using a source and capture the light reflected from the subject using an imaging system. PPGi is a non-invasive and monitors patient without physical contacts thus reduces various difficulties faced in traditional PPG technique. Specially PPGi technique avoids contact which neglects deformation of tissues, hence the signal generated by this method is highly reliable and covers more region of interest [8-9], [27]. Figure 8 Shows the camera with LED being used to acquire image of finger in Non- Contact method of PPGi signal generation.

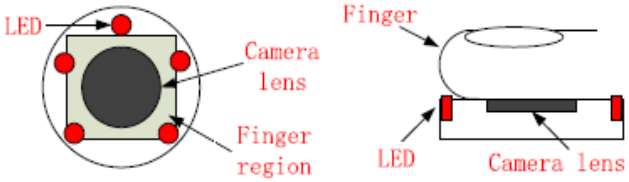


**Fig 8. Acquisition of image in Non-Contact PPGi Method [28].**

### A. PPGi Non-Contact device

The important section of the PPG imaging system is camera, as it captures the image and all the information required are extracted from it. If the quality of image is not good it will have severe impact on the physiological measurement. The image capturing device should be able to adapt to various speed and exposure duration as per necessity. Depending on the wide range of cameras with different characteristics available, PPG imaging device can be grouped into HD camera based PPGi, Digital camera based PPGi and Mobile Camera based PPGi. In HD camera based PPGi, customized light sources are used usually Red/IR LED. Illumination of skin tissue is either taken care of by ring shaped LEDs or array of LEDs. Motionless monitoring is being followed in most of the cases for Heart rate and Pulse oximetry measurement. In Digital camera based PPGi, ambient light source was used. Compared to HD camera based PPGi system this is less expensive and simple. Even several monitoring was done using web camera, during these studies it is observed that blood absorbs green light more compared to adjacent tissues. Tolerance to Motion artifact was considered and tested to monitor vital signs using Web camera based PPGi system. Ambient light intensity changes have not affected the physiological measurement by the system. Mobile Phone based PPGi system white LED is used as light source. Instead of using sophisticated design this system exploits the device that is being used regularly which helps the user to access it easily. Several commercial products are being released using this method to monitor user's physiological parameter like heart rate [20], [29-35]

### B. PPGi Signal extraction from image

The PPGi signal extraction from the image involves several preprocessing, analysis and computation. The initial step would be recording of the subject with a good quality camera with proper ambient light source. Next step is the process of selecting the Region of interest it may either be automated or manual selection can be done. After selecting the desired region and identifying skin pixels and non-skin pixels the spatial domain information about the pixels are obtained. The spatial resolution and SNR should be maintained with appropriate aspect ratio by considering number of pixels. Errors due to motion artifacts are greatly reduced due to techniques based on spatial domain, which eases the separation of noise. Next step is channel selection, the available channels are Red, Green and Blue. The haemoglobin and other tissues have different absorption rate for different wavelength of light. Hence the channels are affected depending on the absorption rate by the region under inspection. The green channel has more variation with respect to blood volume change and less noise. RGB channels are better suited as surrounding tissues may also be considered and motion affects all the channels equally, thus helps in reducing errors due to motion artifacts and produces quality signal. Even five color channels such as red, green, blue, orange and cyan were used for identifying more noises, this also provide wide choice for source light selection.A healthy being will have a Pulse rate of 40 to 240 beats per minute as a precautionary phase filters are designed to remove pulse rate that does not fall under the above category, this phase may also have called as denoising.Finally, for the extraction of physiological parameters heuristic and learning based methods are available which will get the information on pulse amplitude, heart rate and respiration rate directly. Heuristic methods are more vulnerable to noise than learning-based method.Using learning-basedmethod, it is easier to obtain spectral amplitude of red, green and blue channels and other signals like chrominance as well as independent components [31-32], [36-38], [9].

## IV. EXPERIMENTAL RESULT

### Photo Plethysmograph Using Contact Method

Figure 9 shows the PPG signal of a healthy young person with the dicrotic notch with the indication of diastole and systole section.

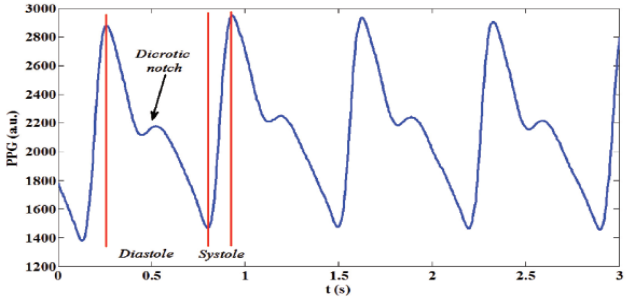


**Fig 9. PPG Signal of a healthy person with its components being pointed [18].**


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## V. PHOTO PLETHYSMOGRAPH APPLICATIONS

PPG finds its application in monitoring of physiological parameters for various purpose. Heart rate monitoring which is a regular parameter used to assess patient condition in almost all the clinics. respiration rate monitoring is also a basic parameter needed to assess condition of patient, Blood oxygen level monitoring by which oxygen distribution in tissues is assessed, Pulse rate variability assessment shows the neural activity in cardio vascular system, Blood perfusion is assessed by which dermal damage can be diagnosed, pulse transit time through which pulse wave velocity can be measured that can be used to diagnose various risk of heart diseases, possibilities of measuring blood pressure continuously but the accuracy level is not much satisfactory, Atrial fibrillation should be monitored regularly to assess risks which is possible using cheaper PPGi techniques, using Systolic and Diastolic peaks artery stiffness can be assessed which provides vital data on cardiac system.PPG technique may be used to design a personal health assistant and support telemedicine[37-39], [9], [18], [2].

## VI. CONCLUSION

In this paper the contact method for obtaining PPG signal and non-contact method for obtaining PPGi signal are discussed. The contact method has several disadvantages and most vital of them all is the motion artifact. The denoising of the effect caused by motion artifact is very difficult which was handled effectively in non-contact method of obtaining PPGi signal. The images obtained are tested against motion artifact and effects are easily denoised. The clear insight of photo plethysmography has been presented and detailed description of the devices that are used is portrayed. Various features that can be extracted from PPG signal are discussed and different methods involved were mentioned. The advancement of technology has given a greater scope for photo plethysmography. Research works on remote PPG has been on the increase from the year 2010. As future enhancement special system can be developed to obtain accurate PPGi signals to measure physiological parameter, in the area of data processing more advanced techniques can be exploited to decrease motion artifacts absolutely. Not only in clinical labs but also instruments that are being used in our day today life will have facilities to measure various parameters just by clicking our image.

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