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Heart Rate Measurement Based on Color Signal Extraction

Ruchika Sinhal, Kavita Singh, Mukesh Raghuwanshi

Abstract: Photoplethysmography measures vital signs through to extraction of signals from the body. The paper explains the technique for extraction of pulse rate from the videos for three color channels namely; red, green and blue. The DMIMS database is used for experimentation which consists of total 720 videos out of which 25 videos are used for analysis. The results presented in this paper depict that our algorithm works best for blue channel followed by green and then red channel. The main focus of paper is to extract pulse rate from the recorded video and compare the output for different channels and find the best channel for heart rate extraction.

Keywords: Photoplethysmography, vital sign monitoring, rPPG, heart rate estimation, color channels.

I. INTRODUCTION

Photoplethysmography (PPG) is a non-invasive optical technology that detects blood volume changes in the micro vascular tissue bed beneath the skin [1]. It has been widely used in (wrist, finger or ear-based) pulse oximetries [2] to record a subject's pulse-rate and peripheral oxygen saturation (SpO2). The principle of PPG relies on optical absorptions of arterial blood on other biological tissue parts in certain light wavelengths [3]. A light source lights up a piece of human skin containing pulsatile blood and a camera captures this. rPPG checking has two steps: region of interest detection and signal generation to detect a pulse.[4] When the pulsatile blood is circulating in the human cardiovascular system, the oxygenated blood circulation leads to fluctuations in the amount of hemoglobin molecules and proteins causing variations in the optical absorption and scattering across the light spectrum. By emitting light through the skin layers and measuring the amount of light propagating in the tissue, we can get a PPG signal that reflects blood volume changes over time. The PPG waveform can further be used to calculate physiological variables (e.g., pulse-rate/heart-rate, pulse-rate variability/heart-rate variability, respiratory rate, SpO2, blood pressure, etc.) and assess cardiovascular states (e.g. arterial diseases, stiffness, aging, etc.)[5]

The typical use of a PPG measurement (that is, pulse oximetry) needs a light source emitting light into the skin (that is, Light-Emitting Diode (LED)) and a photo detector receiving light that has spread through the skin. The light source and photo detector have two different operative modes: transmissive and reflective, depending on their geometric placement about the skin [1]

II. RPPG SYSTEM

Camera-based pulse-rate measurement is an emerging topic. There are variety of abbreviations exist in the literature referring to the same or similar technology, such as remote PPG (rPPG) [6], camera-based PPG (cbPPG) [7], non-contact PPG (ncPPG) [8], imaging PPG (iPPG/IPPG) [9], PPG imaging (PPGi/PPGI) [10], remote imaging PPG (RIPPG) [11], distance PPG (DistancePPG) [12], pulse camera (PulseCam) [13], cardiovascular camera (CardioCam) [14], video PPG (vPPG) [15], video plethysmography (VPG) [16], video-based heart-rate (VHR) [17], vital signs camera (VSC) [18], etc. This may cause confusions when referring the relevant works in the literature, especially to new people entering this field. On the long run, the scientific community should aim for a standardization of the name or abbreviation for this technology. In this paper, we use the term "remote PPG" with an abbreviation "rPPG". A typical rPPG setup is comprised of three components: camera, light source, and human skin, where the light source illuminates the human skin and the camera records this image remotely and sequentially. The camera-signal measured from the skin is the raw input of the rPPG function, i.e., RGB-signals that contain PPG-waveforms. In our study we focus on three color channels RGB which is used to stire the videos acquired.

III. COLOR INTENSITY PEAK COUNT

The proposed system counts the number of peaks in the filtered signal gained from the color intensity calculated from all the frames of video. The intensity is found from the video recorded in a controlled environment. The video recorded is not filtered or corrected for any improvement.

The video is read and the vector of frames is created. The first frame is displayed to record the ROI (region of interest) for finding the pulse count from the exposed area in the video. The "forehead" is chosen as the region of interest. As shown in Fig. 1 the subject have forehead region exposed more and therefore is easy to select and extract signals from with more signal to noise ratio.

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***Correspondence Author(s)**
Ruchika Sinhal*, Dept. of CSE, DMIETR, Wardha, India.
Dr. Kavita Singh, Dept. of CT, YCCE, Nagpur, India
Dr. Mukesh Raghuwanshi, Dept. of IT, YCCE, Nagpur, India

Fig. 1. First frame for subject #5025 with selected ROI

The ROI is kept constant for all the frames in video to extract the color intensity from the selected section of interest. The sum of the pixels is then averaged with the pixels to find the intensity matrix. This matrix is then filtered using the Butterworthband pass filter with lower band of 60 bpm and high band of 100 bpm. The Butterworthband pass filter is chosen as there is lower and upper limit in the signal. The filtered signal is stored in the vector and plotted as a graph as shown in fig. 2. The peaks are counted from the filtered signal which is the output of the beat count.

Input: Test video $V=\{V_1,V_2.......V_N\}$ N is the total number of videos

Output: Beat Count

STEP 1: Read Input video

STEP 2: Video is divided in set of frames $F_n=\{f_1,f_2,f_3,......f_n\}$ n is the number of frames in corresponding video

STEP 3: For $f_1 \in F_n$

Select region of interest manually

STEP 4: Initialize intensity vector to zero

STEP 5: For $f_i \in F_n$ (i=2,3,4......n)

a. Find the intensity from each frame for selected static ROI from f_1 in step 3

b. Save the intensity in the initialized intensity vector in step 4

STEP 6: Filter the intensity vector using Butterworth filter.

STEP 7: Count number of peaks in the filtered signal from step 6

STEP 8: Output the count as beat count for the input video

Algorithm: Color Intensity Pulse Count

IV. RESULT

The proposed approach was experimented using MATLAB R2017b with 32GB RAM, 3.60 GHz Intel Core i7 64 bit processor an 1TB hard disk. For estimating the proposed methodology for estimating heart beat the accuracy of the methodology is found for three color band.

The proposed methodology of color intensity peak count describes the method for estimating the pulse rate from the recorded video. Motion stabilization and illumination correction play vital role in improving the signal to noise ration of the video for estimating vital signs from the video. In this paper, we have experimented on the videos by applying a simple Butterworth filter to estimate the pulse rate from the video. The performance of the proposed method is examined on 20 subjects from the DMIMS dataset.The minimum age of women was 20 and the maximum was 35 in the tested video.

Fig. 2 below represent the thumbnails from the video that are from the 20 videos used for testing. The properties of the video are mentioned in Fig. 2. The duration of the video is between 120-130 seconds. The frame rate for all the videos is same that is 30 frames per second. The resolution of the video is 1280X720 HD quality in mobile phone. The signals extracted from the sample videos are shown in the fig. 2 and fig. 3. The first signal is the plotted signal for the intensity values extracted for each video frame. The second signal is the signal extracted and filtered using Butterworth band pass filter. The Fig. 3 is the extracted and filtered pulse plotted for subject number 5023. All the extracted signals are for the blue channel.

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5006	5007	5008	5025	5024	5023
Duration:121 Frame Rate:30.35 Height:720 Width:1280	Duration:121 Frame Rate:30.35 Height:720 Width:1280	Duration:123 Frame Rate:30.35 Height:720 Width:1280	Duration:122 Frame Rate:30.35 Height:720 Width:1280	Duration:127 Frame Rate:30.35 Height:720 Width:1280	Duration:122 Frame Rate:30.35 Height:720 Width:1280

Fig. 2. Thumbnails for six subjects from DMIMS database with properties of video captured

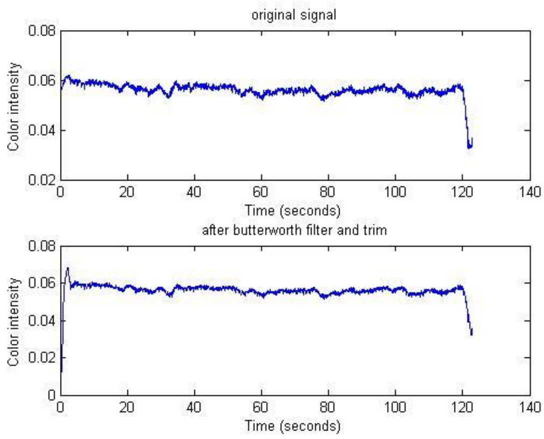

Fig. 3. Extracted pulse and filtered pulse for subject #5023

Table- I shows the accuracy of extracted pulse from the video in 90 sec. The video has been tested for three color channels red, green and blue. The accuracy for the blue channel is found more i.e. 89% without any corrections in the video. The red channel has an accuracy of 79.22% and green channel has the accuracy of 76.82%. The highest accuracy is given by the blue channel followed by red channel and then blue channel at the last.

Table- I: Accuracy of proposed methodology with three different channels using butterworth filter

ID	IxTrend Pulse	Temporal Change		
		Red	Green	Blue
5006	99	78	75	83
5007	101	78	75	96
5008	94	88	92	97
5009	92	79	76	85
5010	91	72	76	85
5011	122	116	114	132
5012	97	74	70	81
5013	94	83	75	96
5014	108	79	81	105
5015	100	95	86	120
5016	138	83	82	97
5017	109	108	101	106
5018	81	101	80	87
5019	99	79	90	93
5020	114	80	84	99
5021	111	72	68	74
5022	131	78	78	89
5023	108	88	81	103
5024	91	83	80	90
5025	147	71	70	77
	Accuracy	79.22	76.82	89.09

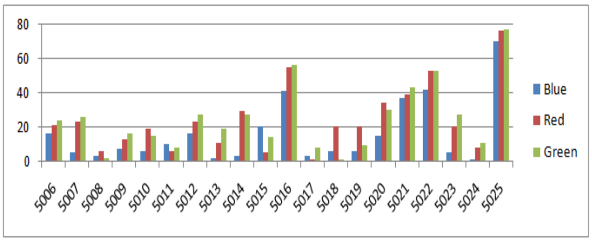

Fig. 4. Difference between the heart rate for color channels extracted

Fig. 4 shows the plot of the difference between the pulse rate extracted from the three color channels of the video and the original pulse rate recorder from MP20 monitor used as gold standard. The minimum difference is found in blue color channel signal filtered using Butterworth filter and then followed by red and then a green color channel. Therefore the blue color channel was good for extracting the pulse rate from the video database captured in research by applying only Butterworth filter to the signals extracted from the ROI.

V. CONCLUSION

The paper demonstrated the method for extracting the pulse rate from the video. The previous research on rPPG follow the controlled environment setting which captured the video from the high resolution digital camera. We have demonstrated the pulse rate counting technique on the video captured through mobile phone which will be useful for monitoring vital signs anywhere. The pulse extracted is compared with the actual pulse rate recorded during the video acquisition thorugh ixTrend software.

The pulse rate is compared with the three color channels red green and blue. Pulse is found to be 89.09% accurate for the blue channel, 79.22 % for the red channel and 76.82% for the green channel. The signal to noise ratio of the video is not improved and so the accuracy of the signal extracted is low. The blue channel gives the best output pulse count from color intensity peak count algorithm, for videos captured through through mobile phones.

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AUTHORS PROFILE

Ruchika Sinhal has completed her Masters from RTMNU in 2012. Her areas of expertise are Machine Learning and Image Processing. She is in collaborative research from past 4 years with DMIMS and has also worked as consultant statistician in project. She worked as Co-Investigator (Engineering) on Collaborative Interdisciplinary project on "Rapid Diagnosis of Frail and Sick Newborns with a handheld sign Monitor'", which is a joint project of Harvard School of Health (Funded under USAID Seed Grant), YCCE, and DMIMS Wardha. Presently Working on THRIVE Multisite Study: OpenSRP for Maternal, Newborn, and Child Health, led by WHO, and supported by the Qualcomm Wireless Reach™ initiative jointly with Summit Institute of Development (SID), Indonesia. She is currently doing research with Dr. Kavita Singh on rPPG techniques.

Kavita R Singh received the B.E degree in Computer Technology in 2000 from RGCERT, Nagpur University, Nagpur, India, and the Mtech.Degree in Computer Science and Engineering from Birla Institute of Technology, Ranchi, India, in 2007, and the Ph. D. degree in Computer Science from the Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, Gujarat, India. She is currently Associate Professor in Computer Technology Department, Yeshwantrao Chavan College of Engineering, Wanadongri, and Nagpur, India. Her current research interests include the area of Data structures, Database, Rough sets, Image Processing, Machine Learning, Pattern Recognition and Near Sets.

Mukesh M. Raghuwanshi received the M.Sc. degree in Applied Electronics in the year 1986 from Amravati University, Amravati, India, and the Mtech. degree in Computer Science & DP from Indian Institute of Technology (IIT),Kharagpur, India, in 1991, and the Ph. D. degree in Computer Science from the Visvesvaraya National Institute of Technology (VNIT), Nagpur, India, in 2007. He is currently Professor in Department of Information Technology, Yeshwantrao Chavan College of Engineering, Wanadongri, and Nagpur, India. His current research interests include the area of Evolutionary computing, Genetic Algorithm, Data structures, Compilers, Programming Languages, DataMining, Machine learning, Computer Vision and Data Warehouse.

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