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rPPG Algorithm for Heart Rate Estimation based on Color Intensity

Ruchika Sinhal[1], Dr. Kavita Singh[2] and Ravi Wasalwar[3]
[1] Dept. of CSE, DMIETR,Wardha, India
Email: ruchisinhal04@gmail.com
[2]Dept. of Computer Technology, Nagpur, India
Email: singhkavita19@yahoo.co.in
[3]Sprint, Reston, Virginia, US
Email: rwasalwar@gmail.com

***Abstract*—With increasing advancements and developments in the field of digital image processing and computer vision, the individual heart pulse can be extracted from human skin surfaces. This method is referred to as remote photoplethysmography (rPPG). The method can also be applied from a video recorded from a consumer-based mobile camera. The paper demonstrates a proposed simple rPPG algorithm that should be simple for any individual to understand and implement that will increase the understanding of the rPPG subject. The paper compares the algorithm designed for RGB color model with the developed rPPG. The comparative analysis of rPPG algorithms demonstrates high performance for green channel as compared to other algorithms**.

***Index Terms*— rPPG, pulse rate estimation, color channels.**

I. Introduction

The heart rate is measure traditionally through the contact method. These methods are electrocardiograms and photoplethysmograms based on electrodes and phototransistors to monitor heart rate. Therefore, an individual has to be dependent on the physician to estimate heart rate and monitor his health.

In past years, much attention is gained by contactless devices for physiological measurement. It is similar to situation where a person can infer physical state from camera clip. Cameras have been one of the proven and the reliable device to measure large set of physiological parameters like heart rate, blood volume, pulse rate, pulse rate variability etc., [1]. Remote photoplethysmography is monitoring heart beat from the recording of individual skin.

In this research we describe a study based on color intensity to monitor the heart rate by extracting pulse count for the video clip provided in UBFC dataset. The video is processed in most basic way to extract the physiological signal finding heart rate of participant. Further the comparative testing of the developed [2] rPPG algorithm was done with the other standard rPPG algorithms developed by researchers and check its performance. We have therefore performed several basic analyses that describe the information about the algorithms comparative accuracy.

The organization of the paper is as follows: Section 2 focuses on related work presented by researchers for

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rPPG techniques and algorithms for heart rate extraction. Section 3 focuses on our manual ROI selection and proposed color intensity algorithm for heart rate estimation. Section 4explains the UBFC dataset used, results and comparative analyses on experimentations performed. The conclusion from the experimentation is described in section 5 in the paper.

II. RELATED WORK

Photoplethysmography measures light absorption in skin tissues and observe blood volume variations occurring during systole activity [1]. The blood volume increases during systole and decreases during diastole. The fluctuations are periodic and it occurs during each heart beat. These variations produce the color variation in human skin made by the pulsatile arteries which can be monitored digitally to extract the heart rate of an individual[3]. There exist different physiological parameters such as breathing rate [4][5], blood oxygen level SpO2[6][7][8], heart rate variability[9]. The authors have also demonstrated the use of PPG to extract the living tissue that easily detects the region of interest automatically from the video [10][11].

Many rPPG based pulse extraction methods have been proposed by researchers viz. blind source separation model based methods, deep learning and design based methods. In the forthcoming section of this paper, we will discuss more about BSS and model based method in this section. For detail review one can refer recent reviews like[12][13] and [14].

BSS satisfy independence and correlation among the different channels in the video sequence. ICA used in comparison is the BSS method developed by Pohet.al., the pulse signal is extracted from raw RGB signals[15]. The BSS was further extended by Lam et.al.,and was applied on random patches and histogram analysis was performed to select the optimal one [16].Later, Wei et.al., used dual ROI to estimate heart rate and respiratory rate simultaneously using BSS[17]. Qi et.al.,proposed joint blind source separation technique which explore correlations between heart rate and facial sub regions [18].

Model based methods estimate pulse by skin optical reflection model demonstrated firstly by Wang et.al., [19]. Chrominance (CHROM) a motion tolerant method was further proposed by De Haanet.al.,toextract pulse signal [20]. The motion component was removed when the chrominance subspace was created from the RGB projection. They used blood volume pulse signals that reduced motion artifacts further in[21]. The projection of plane was further continued by Wang et.al., which is more robust in complex illumination scenario [19].

In this paper, we presented a comparative analysis of various techniques such as Verkruysse’s green channel, Poh’s ICA, De Haan’s CHROM, Balakrishnan’s BCG rPPG algorithms with our proposed heart rate estimation technique in [2].

III. METHOD

In this section, we present the framework of proposed rPPG-based HR extraction method depicted in figure 1. Initially, the video of face region is recorded using a color camera. Subsequently, region of interest (ROI) is selected manually from the frame which is passed to the loop. Then the pixels with-in ROI are averaged to get the intensity vector of the pixel in each frame of the video. Three intensity vectors are extracted based on the three main color channels red, green and blue from the ROI part of the video. These extracted signals are further filtered by applying Fast Fourier Transform (FFT) algorithm and the signal is then given to peak counting algorithm. The numbers of peaks counted are the beats count for the video obtained for each corresponding signal. In the subsequent subsections, we discuss the proposed rPPG algorithm.

A. Proposed rPPG algorithm

Recently, there has been numerous work related to rPPG in literature that has been reviewed in the review section. Our proposed algorithm is presented in [2]. The ROI selected is then averaged for three color channels red, green and blue called intensity vector. The averaged value is stored in the intensity vector which is equal to size of number of frames in the video as shown in figure 2. This vector is then further filtered using FFT to filter the non-physiological range of heart rate with Butterworth low pass filter with cut-off frequencies 0.2 to 3.5 Hz. This filtered signal is then counted for number of peaks in the signal. The output is computed for all the three channels separately. This process is repeated for all the candidates.

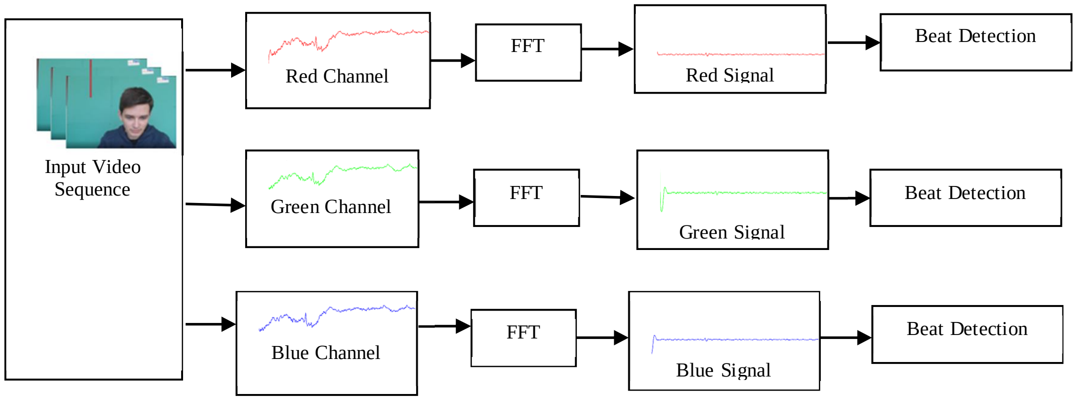

Figure 1 Video-based physiological extraction of heart rate flowchart

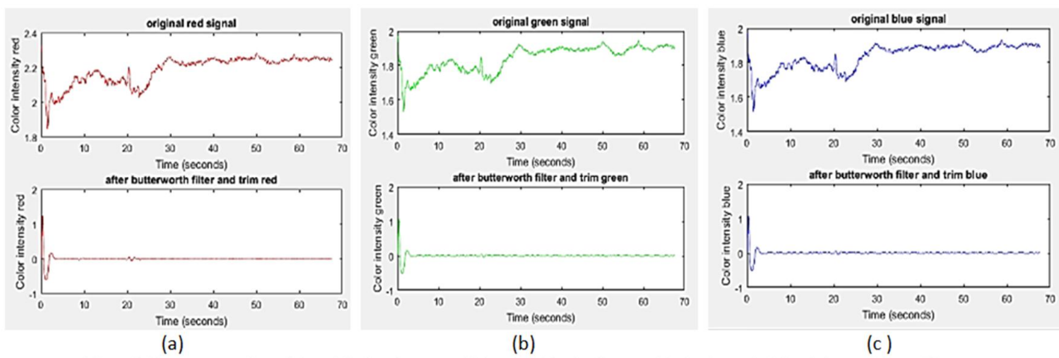

Figure 2:The representation of the original red green and blue signal in the figures with the filtered signal for participant #8

IV. Results

The main focus of the paper is to present a comparative analysis of rPPG algorithms reported in literature along with our proposed rPPG algorithm. The work presented in the paper has been evaluated on UBFC-rPPG dataset and comparative analysis is further presented in 4.2.

A. Comparative Analysis of rPPG Algorithms

This section presents the comparative analysis of the results of our proposed color intensity rPPG algorithm with Verkruysse's green channel, Poh's ICA, De Haan's CHROM, Balakrishnan's BCG state-of-art rPPG algorithms for the UBFC database described in database section earlier. The color intensity algorithm is implemented to extract the heart rate from three main channels namely red, green and blue. The heart rate was extracted from the video and compared with the ground truth values for 40 participants. The Pearson correlation table is shown in table1. This shows the correlation between different algorithms and the ground truth value. Next, we examined heart rate with ground truth and calculated and tabulated the Spearman's correlation in table 2.The heart rate measurements for green channel intensity where highly comparable to ground truth values ($rho=0.3555, p<0.05$). The other measurements were not significantly positive as the p-value was not significant.

The table below is the correlation matrix with Pearson correlation for the extracted result with ground truth.

The table I shows that the ground truth heart rate has highest correlation with the heart rate estimated from the green channels color intensity followed by implementation based on Green Channel –Verkruysseet.al. From table I it can also be observed that correlation has been the least with the blue color channel intensity.

The overall algorithms are inspected with ground truth by applying t test for analysis (table III for means and standard deviation and table IV for statistical comparison) indicated that CHROM was [$F(2, 40) = 39.625$, $p<0.001$] was significantly more accurate compared to other rPPG algorithms. The red intensity gave good outcome followed by blue the green channel.

TABLE I: CORRELATION MATRIX FOR UBFC DATASET

	Ground Truth	Red	Green	Blue	Green Channel	ICA	CHROM	BCG
Ground truth	1							
Red	0.08	1						
Green	0.3496	0.4252	1					
Blue	0.0444	0.8405	0.6486	1				
Green Channel	0.3195	-0.1006	0.2671	-0.0085	1			
ICA	0.1083	-0.0396	0.0894	-0.1002	0.7082	1		
CHROM	0.2467	0.0089	0.4014	0.1677	0.3717	0.4115	1	
BCG	0.2697	0.2962	0.2795	0.1485	-0.0137	-0.1233	0.1198	1

TABLE III: MEAN AND STANDARD DEVIATIONS OF ABSOLUTE DIFFERENCE BETWEEN RPPG AND GROUND TRUTH

Algorithms	Mean	Standard Error	Standard Deviation
Red	50.875	6.372	40.297
Green	47.6	5.195	32.859
Blue	50.675	6.071	38.400
Green Channel	73.638	5.369	33.956
ICA	68.238	6.216	39.312
CHROM	39.625	5.805	36.715
BCG	80.9518	5.319	33.645

TABLE IV: T TEST COMPARISON BETWEEN GROUND TRUTH VALUE AND ESTIMATED HEART RATE

Algorithms	*t* value	*p* value
Red	7.9847	<0.0001
Green	9.162	<0.0001
Blue	8.3462	<0.0001
Green Channel	13.7154	<0.0001
ICA	10.9781	<0.0001
CHROM	6.8258	<0.0001
BCG	15.2169	<0.0001

V. CONCLUSION

The comparative study presented in the paper targeted the basic goal of developing a simple algorithm to extract the heart rate of participant from a video and its comparative analysis with other rPPG algorithms reported in literature. We demonstrated the algorithm and tested it on 40 participants. From the comparative analysis presented, it has been observed that rPPGs accuracy had not been reported by previous studies with a relatively simple method such as the technique proposed by us.

Experimentally, we presented that rPPG can detect heart rate from the intensity of green channel more accurately by our proposed algorithm as compared to other rPPG algorithms reported in literature. The method implemented by us outperformed the other state-of-art rPPG algorithms also Verkyusses algorithm. From the experimental results and comparative analysis it has been observed that still improvement is required to de-noise the signal for the challenges like illumination and motion tracking in the algorithm which can further improve the performance of rPPG algorithms.

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