CONTACTLESS HEARTBEAT MEASUREMENT SYSTEM USING IMAGE PROCESSING

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Abstract

Heart Rate (HR) is one of the most important Physiological parameter and a vital indicator of people's physiological state and is therefore important to monitor. Monitoring of HR often involves high costs and complex application of sensors and sensor systems. Research progressing during last decade focuses more on noncontact based systems which are simple, low-cost and comfortable to use. Still most of the noncontact based systems are fit for lab environments in offline situation but needs to progress considerably before they can be applied in real time applications. This paper presents a real time HR monitoring method using a webcam. The heart rate is obtained through facial skin color variation caused by blood circulation. Three different signal processing methods such as Fast Fourier Transform (FFT) have been applied on the color channels in video recordings and the blood volume pulse (BVP) is extracted from the facial regions. HR is subsequently quantified and compared to corresponding reference measurements. The obtained results show that there is a high degrees of agreement between the proposed experiments and reference measurements.

ABBREVATIONS

CVDs Cardiovascular diseases

CHDs Coronary heart diseases

ECG Electrocardiogram

BBHE Brightness preserving Bi-histogram Equalization

FFT Fast Fourier Transformation

DFT Discrete Fourier Transformation

Introduction

The non-contact physiological parameters monitoring idea has come from the cardiovascular system of human body. The cardiovascular system permits blood to circulate in the body due to continuous blood pumping by heart. Our Heart pumps blood through the blood vessels of this system and for each heart beat blood circulation creates color variation in Facial skin. Therefore, it is possible to extract HR from the color variation of the facial skin. In 1995, the first noncontact health monitoring system was investigated by Costa et al. They used camera images in order to extract physiological parameters using color variation of the skin. But their approaches did not report quantitative results; they reported only a graph of heartbeats and also failed to show any correlation with reference ECG signals. After this first attempt further progress was moderate and in 2005 another novel method was introduced for the measurement of computer user's emotional state using the facial thermal

Heart rate is a crucial factor for the diagnosis of heart diseases and one of the dominant parameters for cardiovascular diseases. Heart rate is defined as the rate at which heart contracts per minute. It is a vital physiological signal measured in the human body that reflects the physical and mental state. Heart rate variability is a measure of variations between each heartbeat that indicates the effects of stress on a person's body. With the rise of unhealthy eating habits and sedentary lifestyles across the world, mortality rates due to cardiovascular diseases (CVDs), stroke, septic shock, coronary heart diseases (CHDs) are rapidly increasing. Ischemic heart disease and stroke are the two major cardiovascular diseases responsible for 80% deaths in India. Therefore, the adaption of a healthy lifestyle with the regular examination of heart rate is essential to keep these diseases at bay.

Standard medical techniques to monitor heart rate are Electrocardiogram (ECG) and Pulse Oximeter sensors. These conventional methods provide accurate heart rate but the application of these devices can cause damage to elderly skin. Moreover, wearing these devices for long time duration can cause extreme discomfort to patients. Also, it cannot be used on neonates. Due to the complex hardware, usage of these machines at home can become complicated without any specialist's supervision. Therefore, interest is growing to measure heart rate without any contact between patients skin with the hardware so that it can be measured without any discomfort.

Photo plethysmography (PPG) is a technique that measures the changes in blood volume caused by scattering of light due to the flow of blood in the body parts. Because of its non-contact nature of sensing, PPG is currently gaining popularity. Face images captured by using the camera carries information about minute color changes in the skin caused due to the beating of heart, blinking of eyes and other physiological activities occurring in the body that generates pulse wave signals which cannot be seen by the naked eye. For computation of these crucial physiological signals from facial videos, researchers have designed approaches.

Pho et al. presented a methodology which measured heart rate by separating red, green and blue color channels from a facial video and employed independent component analysis (ICA) on them. Won et al. implemented Fast Fourier Transformation (FFT) on normalized red, green, blue channels and the heart rate was extracted from ICA by analyzing color channels which proved that although all color channels contain PPG signals, but the green channel possesses the strongest one. But the results got worse due to the application of ICA. Garala A. et al. designed an approach that extracted the spectrum of the Red, Green and Blue color channels using Discrete Fourier Transform (DFT) to which theorem of z-score was applied for data standardization.

Architecture of System:

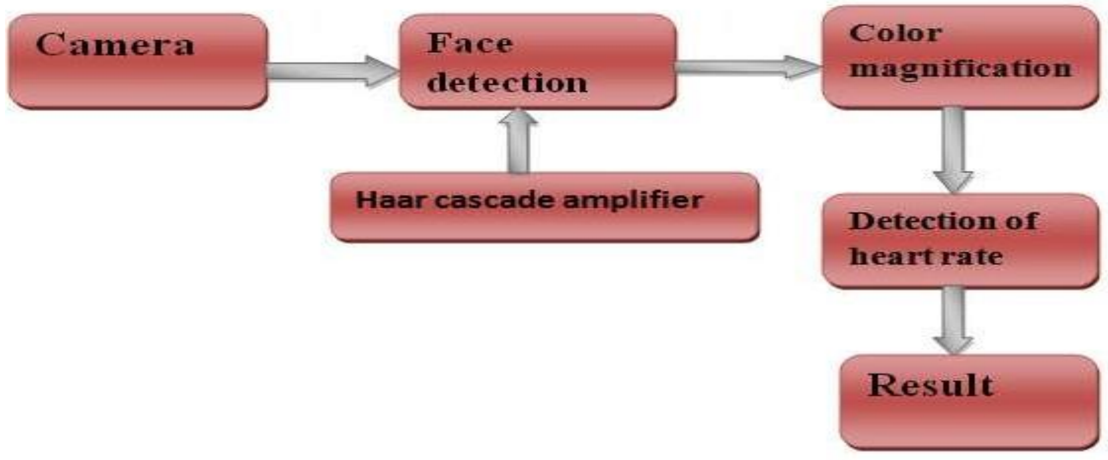

Fig 1.1 System Block Diagram

Working:

- Fig shows the block diagram of heartbeat detection system. In this system to detect the person's heartbeat first person's face detected using face detection algorithm using webcam.
- For detection of face haar cascade classifier is used. Haar Cascade is a set of Haar-Like Features that are combined to form a classifier. Feature is the sum of pixels value in the white subtracted from the pixels value in the black area.
- The base of the face detector is 24 × 24.After face detection it given to color magnification block where it will do ROI selection, filtering, normalization using this some process finally heartbeat is detected.

Problem Statement:

Heart rate is a crucial factor for the diagnosis of heart diseases and one of the dominant parameters for cardiovascular diseases. Heart rate is defined as the rate at which heart contracts per minute.

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- Heart rate variability is a measure of variations between each heartbeat that indicates the effects of stress on a person's body.
- With the rise of unhealthy eating habits and sedentary lifestyles across the world, mortality rates due to cardiovascular diseases (CVDs), stroke, septic shock, coronary heart diseases (CHDs) are rapidly increasing. Ischemic heart disease and stroke are the two major cardiovascular diseases responsible for 80% deaths in India. Therefore, the adaption of a healthy lifestyle with the regular examination of heart rate is essential to keep these diseases at bay.

Objectives

1. Design machine learning based system for detection of heartbeat.
2. Give the prevention and cure for the heart related problem.

Help find the cause of symptoms, such as an irregular or rapid heartbeat (palpitations), dizziness, fainting, chest pain, or shortness of breath

Working of System-

During the heartbeats the blood is pumped throughout the body, causing skin color variations. These changes cannot be observed with the naked eye but can be detected in a video stream. To implement the image processing algorithms, it is necessary to choose a region of interest, which is relevant in the sense of being able to observe how the pixels in the selected area change their intensity. By averaging the intensity of the skin color and extracting the frequencies that appear in the signal, a clear peak will appear which represents the frequency of the heart beats. In order to accomplish the project, the pixels within the selected region of interest are processed in the Spyder development environment, using OpenCV and Python.

1. **Reading Image Frames**

An image frame is the fundamental part of a video or any image source that indicates the start and end point of a video which represents a silent part of that video. Fig. 1(a) shows the real time HR monitoring system to extract a number of image frames one by one at a certain period of time defined by the user. It is also important to notice that the resolution of the video should remain same during each image frame extraction for further calculations. Therefore a novel key frame video extraction algorithm has been used to maintain same resolution that can read image frames automatically one by one.

A. Face Tracking

Facial image is the input of the proposed non-contact HR monitoring algorithm and therefore it is very important to track facial part of the user. The real time method needs a powerful face tracking method to perform higher face detection rate. After extracting an image frame in real time, the automatic faced detection function '*CascadeObjectDetector'* of Computer Vision Toolbox provided by MATLAB[2] was applied which has been implemented using Viola and Jones method. Later the function was modified to fulfill our own purposes. Fig. 1(b) indicates the detected face.

B. Region of Interest Selection

R, G and B color values of each pixel of the facial image frames are the most essential part for this experiment. Hence it was searched a perfect Region of Interest (ROI) over the detected face. The detected face using Viola and Jones method contains some unwanted part which needs to eliminate. To identify the coordinates of the face location in the first frame a boosted cascade classifier was used for the *x* and *y*-coordinates along with the height and width that define a box around the face according to the method in. Therefore the center was selected as 60% width and 80% height of the box as the region of interest which is free from unwanted parts. Only the ROI was then separated from the entire facial image shown in Fig. 5.1(c) and this ROI is used for further calculations.

C. RGB Signals Extraction

R, G, B color values are the fundamental elements of R, G and B signals (together they are called RGB signals) which were extracted from the facial cropped RIO image [40]. Each pixel of the image has 3x1 matrix of color values which consists of Red (R), Green (G) and Blue (B) color of the image. Then the three desired signals Red, Green and Blue signals are produced in two phases. In the first phase the average R, G and B color values are calculated for each image frame shown in Fig. 5.1(d) and in the second phase the red, green and blue signals are calculated from the summation of all the averaged R, G and B color values indicated in Fig. 5.1(e- g).

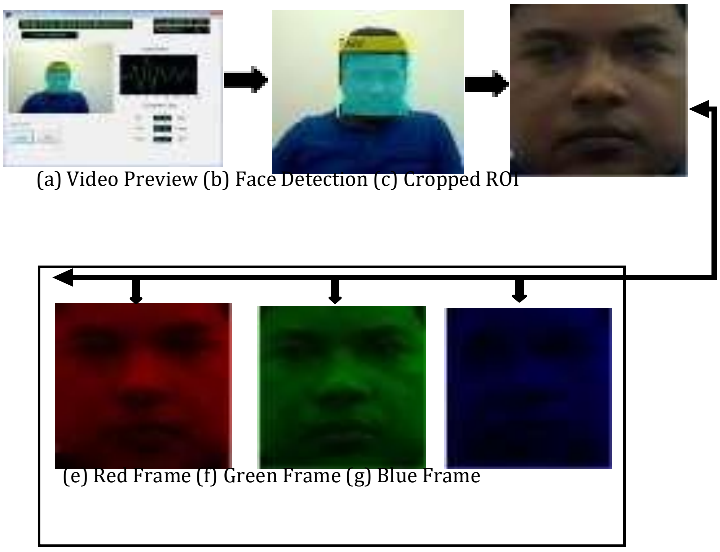

Fig 5.1. Feature Extraction from each image frame

D. Signal Detrending

Detrending is an important signal processing concept which is used to remove unwanted trend from the series. Detrending of signal is useful when it is thought that a feature is distorted from the relationships of interest. In our case, when environmental parameters changes such as temperature or external noise, the collected RGB signals will be drifting and noising. Therefore the signals need to detrend. The RGB signal has been detrended using the method used in based on smoothness priors approach with the smoothing parameter λ =10 and cutoff frequency = 0.059 Hz shown in Fig. 5.2(h).

E. Filtering

Before applying PCA, ICA and FFT the Red, Green and Blue signals in Fig.5. 2(d-f) formed from all red, green and blue image frames in Fig. 5.2(a-c) are filtered by Hamming window (128 point, 0.6-2 Hz, for normal HR 36-120) for heart rate

Shown in Fig. 5.2(j).

F. Normalization

The signal needs to be normalized and the normalization has been performed according to the method mentioned in

In Fig. 5.2(i). Equation (1) shows the normalization formula as below:

$X\,(t) = \underline{Y_i(t) - \mu_i(t)}$

For each i = R, G and B signals where μ_i is the mean and

δ_i is the standard deviation of Y_i

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 05 | May - 2022 Impact Factor: 7.185 ISSN: 2582-3930

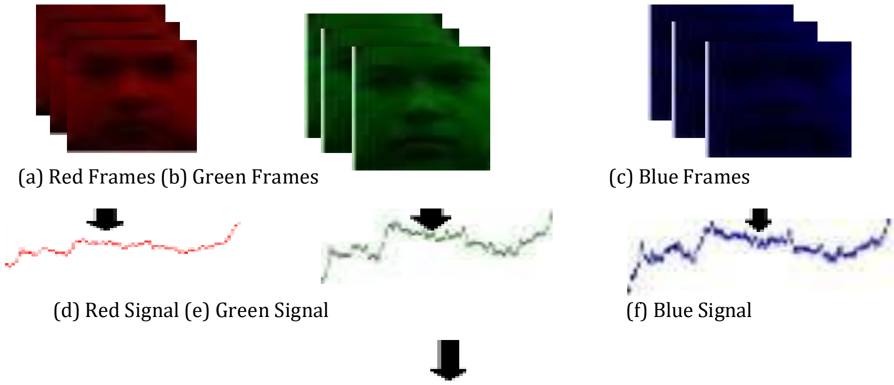

Fig 5.2 R, G,B Signals

RESULTS AND DISCUSSION

HR was extracted and recorded for 5 minutes for all the 10 test persons in real time using webcam and cStress system using ECG sensors and the extracted HR values were saved in two different excel files. After 5 minutes the real time session was over and HR was extracted again in offline using the saved film sequences using the proposed algorithms of. For each test subject there were 3 separate excel files for the extracted HR; one was for real time method, another one for cStress system for reference and the last one for offline

TABLE I. STATISTICAL ANALYSIS OF HR IN REAL TIME VS OFFLINE CONSIDERING CSTRESS SYSTEM

SUBJECT	PARAMETERS	Real Time			Offline			CSTRESS
		FFT	PCA	ICA	FFT	PCA	ICA	
1	min	46	51	52	63	54	60	64
	max	98	99	90	88	98	88	87
	mean	71	73	70	77	76	78	76
	std	7	9	7	5	7	4	4
	median	70	72	69	77	76	78	76
	min	57	59	57	58	51	64	53

	max	89	91	89	99	99	99	64
2	mean	73	76	73	74	76	74	56
	std	6	5	6	5	6	5	2
	median	73	76	73	73	77	73	56
	min	57	59	57	61	63	64	58
	max	90	99	90	99	99	99	71
3	mean	76	75	76	79	80	80	64
	std	7	5	7	4	5	4	3
	median	78	75	78	80	80	80	64
	min	54	61	54	54	60	54	64
	max	91	99	91	94	90	94	85
4	mean	82	78	82	82	77	82	73
	std	6	6	6	6	4	6	4
	median	83	78	83	84	77	84	72
	min	51	50	59	55	50	61	41
	max	99	99	99	99	99	99	93
5	mean	71	74	72	72	75	75	61
	std	6	6	6	6	7	7	8
	median	71	74	72	71	75	74	61
	min	63	59	63	55	61	55	71
	max	90	96	90	94	95	94	90
6	mean	78	77	78	79	77	79	77
	std	5	7	5	6	6	6	3
	median	77	78	78	79	77	79	77
	min	46	51	52	64	58	64	61
	max	98	99	90	95	99	95	99
7	mean	72	74	70	77	78	77	70
	std	7	10	7	6	5	6	7
	median	70	72	69	76	77	76	68
	min	51	50	59	54	51	67	71
	max	99	99	99	99	90	99	98
8	mean	71	74	72	82	77	83	83
	std	6	6	6	6	5	6	4
	median	71	74	72	83	77	83	84
	min	65	58	74	66	52	74	66
	max	98	97	98	92	99	92	95

9	mean	87	84	87	87	84	87	81
	std	3	4	3	3	5	3	5
	median	70	72	69	77	76	78	76
	min	47	50	48	61	53	58	66
	max	98	99	88	87	96	90	87
10	mean	72	73	68	76	74	76	76
	std	7	8	7	6	7	5	4
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Method. It is necessary to do statistical analysis to find out the efficiency of the proposed method with respect to reference sensor system. Therefore several parameters such as minimum, maximum, average, median and standard deviations were calculated from the extracted HR for the real time extraction method, cStress system and offline method. These statistical parameters for all the 10 test persons are presented in table I. For the evaluation then it is necessary to calculate some statistical analysis. Therefore, the evaluation was made using 2 important statistical parameters such as RSQ (R-squared) and CORREL (Correlation Coefficient) for both real time and offline HR extraction considering cStress system.

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