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Real Time Heart Rate Monitoring from Facial Video using Independent Component Analysis Algorithm

Raparthi Navateja[1], Swapna A[2]
[1]*UG Student, Dept of Computer Science and Engineering, Mahatma Gandhi Institute of Technology,Hyderabad, Telangana, India*
[2]*Asst Professor, Dept of Computer Science and Engineering, Mahatma Gandhi Institute of Technology, Hyderabad, Telangana, India.*

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 project presents a real time HR monitoring method using a webcam of a laptop computer. The heart rate is obtained through facial skin color variation caused by blood circulation. Some of the signal processing methods such as Fast Fourier Transform (FFT), Independent Component Analysis (ICA) have been applied on the color channels in video recordings and the blood volume pulse (BVP) is extracted from the facial regions. The obtained results show that there is a high degrees of agreement between the proposed experiments and reference measurements. This technology has significant potential for advancing personal health care and telemedicine. Further improvements of the proposed algorithm considering environmental illumination and movement can be very useful in many real time applications such as driver monitoring. This can be used for gaming purpose where the real heart rate of the person can be felt for the character present in game.
Keywords: Heart rate detection; independent component analysis; non contact measurement

I. INTRODUCTION

The heart rate (HR) of a person represents the number of heart beats per minute. It is an essential physiological parameter, a source of information related to the entire cardiovascular system and has great importance in diagnosis or assessment of the stress levels experienced by the person. The heart rate normal values differ depending on the age, medical history or usual physical activity. For example, people who are less physically active are expected to have a higher heart rate, as their heart muscle has to work harder to maintain a constant cardiac rhythm. It has been well-known for decades that any unusual variations of the cardiac pulse have to be taken into consideration for further investigation and diagnosis.

As a consequence of society becoming more health conscious, various concepts of remote health monitoring platforms are developed. Among others, these also include supervising elderly people or chronic diseases patients from residential environments. Also, there are situations in which continuous heart rate monitoring is required but skin contact is problematic, and the patient feels uncomfortable to be continuously connected to a pulse measuring apparatus.Research exhibits significant advancements over the last few years and demonstrates that standard video cameras are reliable devices that can be employed to measure a large set of biomedical parameters without any contact with the subject.

Photoplethysmography (PPG) and Ballistocardiography (BCG) are the two main principles for measuring pulse rate in video streams recorded by a camera. Ballistocardiography relates to the observation of small body displacements that appear during systole (cardiac contraction). Photoplethysmography consists in indirect observation of blood volume variations by measuring absorption and reflection of light on skin tissues.These fluctuations in volume are periodic and produced at each heartbeat: the volume of blood increases during systole (cardiac contraction) and decreases during diastole (cardiac relaxation).It must be emphasized that the definition of the principle is still discussed today: light variations that are remotely measured by the camera might be related to elastic deformations of the capillary bed, by a rise of the capillary density that compresses tissues during systole, instead of a direct observation of the changes in sections of the pulsatile arteries.

We present a new approach to contact-free methods for measuring heart rate using video processing. This technique requires the subject to be relaxed and to be placed near a webcam. The distance between the camera and the patient can vary between 75cms to 100 cms, and the illumination conditions have to be constant during the process. In order to measure the heart rate in real time, image processing will be performed using OpenCV and implemented in Python programming language.

II. PROPOSED METHODOLOGY

The main idea behind our method is that the color of the skin changes as blood flows through the face which is not visible to naked eyes but is identified by the cameras.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 this paper we have used two techniques to estimate the heart rate. Both the techniques involve Fast Fourier Transform to convert the signal extracted to frequency. One of them involves ICA to extract the signal where as one don't.

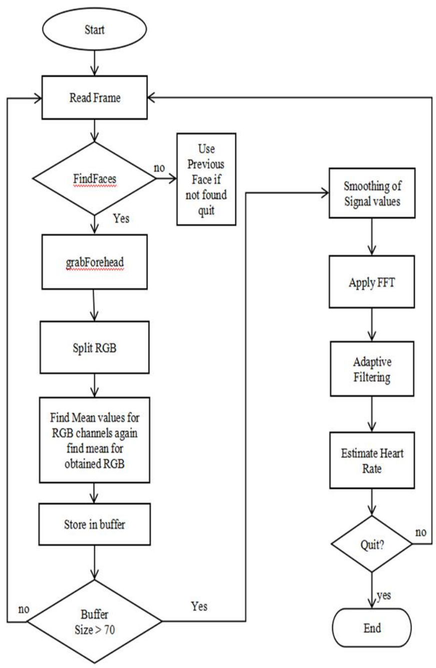

Fig. 1. Flow Chart of Estimation of Heart Rate without ICA

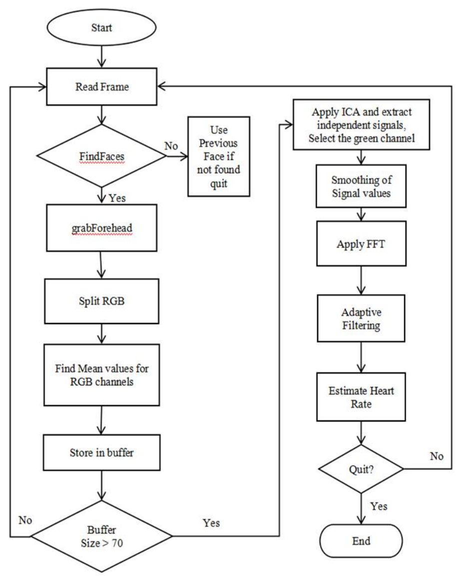

Fig.2.Flow Chart of Estimation of Heart Rate with ICA

A. Capture the Video Using Webcam

The subject (Human) is made to sit in front of the webcam and the video is captured for nearly about 10 seconds.

B. Identification of Face

Viola-Jones algorithm[1] is used for face detection. The qualities of this algorithm are high identification efficiency and low false-positive incidence, Practicality etc. This algorithm has the four stages which include Selection of Haar Features, Integral Image Creation, Training using Adaboost learning algorithm, Cascade of Classifiers.

C. Selection of Haar Features

Each human face has certain characteristics which are comparable. A few features commonly seen in human faces are:(a) the upper cheeks are lighter than the edge of the eye (b) the region between the eyes is darker than the nasal bridge. Those comparisons can be organized utilizing haar features. The properties of the facial components are: (a) scale and location of nose bridge, lips, eyes (b) pixel intensity gradients (Eq . 1)

$$value = \sum(black\ region\ pixels) - \sum(white\ area\ pixels) \quad (1)$$

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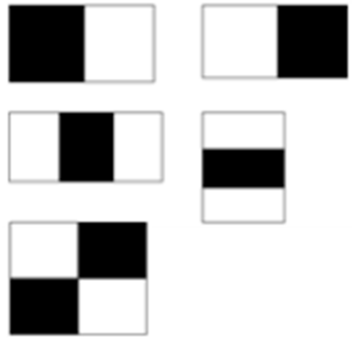

Fig. 3 Haar features

D. Integral Image Creation and Training using Adaboost learning algorithm:

The rectangular characteristics are evaluated by the integral image in constant time, which increases the calculation speed compared to other approaches where more attributes were used and extended the computation time. The speed at which features are processed does not depend on their number. Therefore, an Adaboost technique is used by the face detection algorithm not only to select the best feature but also to train classifiers.

E. Cascade of Classifiers

Each stage of cascading has a strong classifier. Here all the required components are assembled into multiple stages where each stage consists of a certain number of elements. Each stage's role is to detect whether a given sub-window is undisputedly a face or not. if perceived sub-window is not a face it will be automatically discarded.

F. Region of Interest

The region of interest is an area of the image, selected on specific criteria, which is to be used during the computational process. In order to observe the skin color variation, the most suitable area is the forehead as it provides detailed changes encountered. The dimension of the rectangle placed on this area is in respect to the facial detection box, as its size changes depending on the distance between the subject and the webcam.

G. 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 ROI image. 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 used in two ways. In the one of the approach, the average R, G and B color values are calculated for each image frame, we use this for the approach that involves ICA. We again calculate the mean of these averaged R, G and B signals and use them for approach without ICA.

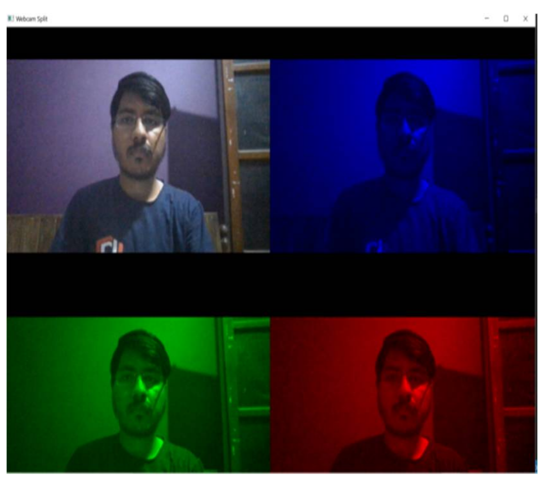

Fig 4. Example Image of Splitting into RGB signals

H. Independent Component Analysis

Independent Component Analysis (ICA) is a computational method for separating a multivariate signal into additive subcomponents by assuming that the subcomponents are all statistically independent from each other. In this paper we used FastICA to extract the signals. This step is avoided in the approach that has no ICA. FastICA is an efficient and popular algorithm for independent component analysis invented by Aapo Hyvärinen at Helsinki University of Technology.Like most ICA algorithms, FastICA seeks an orthogonal rotation of prewhitened data, through a fixed-point iteration scheme, that maximizes a measure of non- Gaussianity of the rotated components. Non-gaussianity serves as a proxy for statistical independence, which is a very strong condition and requires infinite data to verify. FastICA can also be alternatively derived as an approximative Newton iteration.

I. Measuring the Heart Rate

The FFT (Fast Fourier Transform) is applied to the window formed by the last 70 values of the signal obtained at the previous point. Since normal heart rates are between 35 and 195 beats per minute, frequency filtering can be applied to correct false readings. The heart rate translates to a frequency between 0.5 Hz and 3 Hz. We find the maximum frequency in the buffer size. If we use the approach using ICA we get three frequencies, we select the maximum of three, as we can't say which corresponds to R, G and B signal.

To calculate the heart rate, the formula is as follows:

$$HR = 60*f \qquad (2)$$

HR is the heart rate and the f is the extracted frequency of the heart rate.

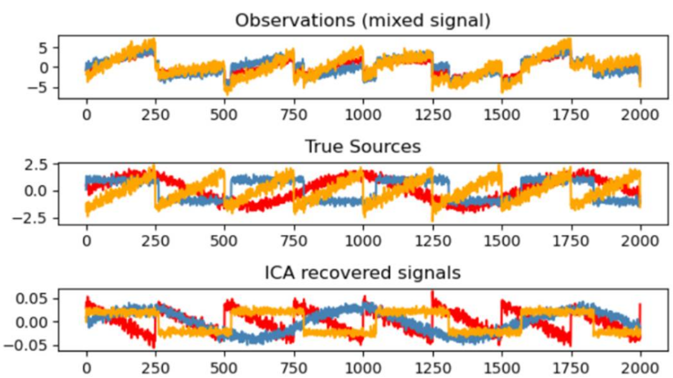

Fig. 5.Example showing how FastICA is used in extracting the individual Components

III. RESULTS

It is the concept of this project that the application should not require any special equipment.We design the system as such that it can run on any personal computer equipped with a camera.The prototype system has been tested on a desktop personal computer (2.1GHz Ryzen Quad core processor, 8GB RAM) equipped with a sound card and inbuilt web-cam. I have used the Region of Interest as forehead rather than whole face identified.The subjects were estimated heart rate under good lighting conditions such that there is even amount of light over there forehead. The estimated heart rate depends on the amount of light present around. Some time skin color of the person also matters. But under given sufficient light, we get good results. The subjects are made to sit in front of camera for around 10-15 seconds, to estimate the stabilized heart rate.

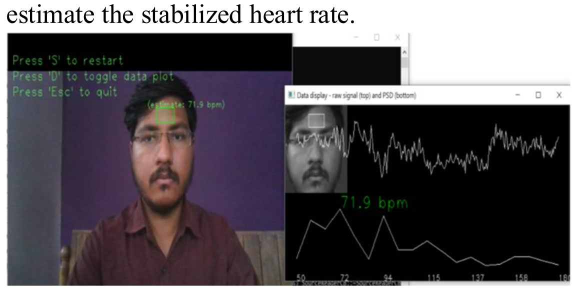

Fig 6.Screenshot of Heart Rate Estimated without ICA

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The subjects have tested under ambient light condition under different situations. When we tested the subject around 10 times and got the readings for both approaches i.e with ICA and without ICA.In addition to this, Heart Rate tests were done parallel with one of the heart rate monitoring device oxymeter to ensure the accuracy of the measurement. The result from the oxymeter is considered as the ground truth, which might not be the exact because their might be instrument error.

By my both the approaches, I have achieved the heart rate with the error rate of ±3bpm to ±6bpm given sufficient light conditions for the approach without independent component analysis and with help of independent component analysis the error rate is ±4 bpm to ±7 bpm.Since the calculated heart rate was consistently lower or higher than the reference in all videos and with small standard deviation, it is possible that the base error is due to a miscalculation in video frame rate or finger pulse sensor sample rate.The results can be further improved if we use high definition camera with higher fps.

Fig 7.Screenshot Heart Rate Estimated with ICA   Fig 8.Reading from Oxymeter

IV. CONCLUSION

Based on our tests, we can say that we have achieved our goal of developing a prototype system for a real-time non-contact hr tracking system utilizing facial video that is easy to execute, low price, and convenient for real-time applications. Based on the experimental findings, assumed that the hr differs in normal conditions varies from 60 to 110 bpm. This application is platform independent. The source code is written in python. The opencv (open source computer vision) libraries are used for image and video processing purpose time. We can combine it with ir camera or sensor to improve the results further.

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V. FUTURE SCOPE

Due to the widespread availability of cameras specifically webcams, this contactless technology is promising for medical care and other indoor applications. Few factors such as variable ambient lighting or head movement should be considered for future applications like driver monitoring in outdoor environments. In addition, to improve performance, more test subjects and more testing systems need to perform the experiment. While this paper only discussed the recovery of cardiac HR, it is possible to estimate many other significant physiological parameters such as Respiratory Rate, Heart Rate Variability, and blood oxygen saturation using the technique proposed. Future research will be around building a real-time, multiparameter physiological measurement network with higher video resolution based on this technology in real-time.

This can also be applied for driver monitoring, telemedication. It can also be used for gaming purpose, the real time heart rate is fed to the game character and corresponding sound for the heart rate can be given for the ingame character. We can actually feel that we are playing the game.

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