Contactless Heart Rate Measurement Using Non Invasive Technique

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Abstract--This paper deals with the implementation of non-invasive method of heart rate measurement by processing the video of the subject's face. The skin color variations as blood fills the face which are not visible to naked eye, can be observed through a technique called Eulerian Video Magnification. It applies spatial decomposition followed by temporal filtering and amplification to the standard input video sequence. Heart rate can be extracted from this magnified video by considering small region of interest. Heart rate of 28 year old subject was measured as 70 bpm using conventional method and 68 bpm using webcam. This result gives accuracy about 97%. Heart rate of 4 year old subject was measured as 95 bpm using conventional method and 92 bpm using webcam. This result gives accuracy about 96%. This technique can run in real time to reveal hidden information in videos.

Keywords—Eulerian video magnification, spatial decomposition, temporal filtering.

I. INTRODUCTION

The measurement of human heart rate is one of the most important parameter in diagnosing medical conditions. There is significantly high demand for new methods of easy, unobtrusive, and personal health care and monitoring technology. Most of the current technologies require direct physical contact with the patient in order to achieve proper measurement. The physical contact consists of electrodes on Electrocardiogram (ECG) machines, or pressure sensors on major arteries such as a wrist band, watches, fingerclips, holder monitor, etc. as shown in Fig.1.

Fig.1 Current methods of heart rate measurement

However this recent technique of Eulerian Video Magnification is a very reliable non-intrusive technique for the measurement of heart rate. It is desirable for an individual to obtain a low resting heart rate between 50 and 70 beats per minute (bpm) and an active heart rate between 100 and 150 bpm. Our study strives to eliminate all of the abovementioned limitations of heart rate detection technology. The human visual system has limited spatio-temporal sensitivity, but many signals that fall below this capacity can be informative. For example, human skin color varies slightly with blood circulation. This variation, while invisible to the naked eye, can be exploited to extract pulse rate [5]. Fig.2 shows the experimental setup of the project.
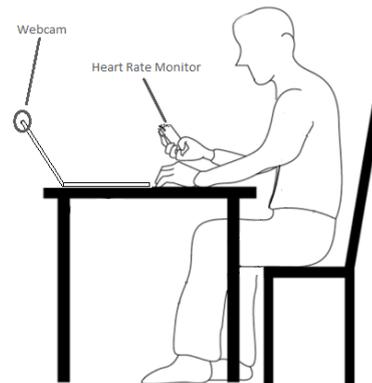

Fig.2 Experimental Setup

II. EULERIAN VIDEO MAGNIFICATION

The Eulerian Video Magnification of amplifying subtle changes in video stream was presented at SIGGRAGH2012 [2].

There are two main video based methods for the non-contact measuring at the present time. The first one is based on monitoring small movements of the body caused by reaction to the waves of blood pushed from the heart. The second one is based on small changes in skin color caused by the blood flow in tissues. The reflection capability of as kin with capillaries supplied with blood differs from the reflection capability of a skin containing less blood. The blood volume is changing in correspondence with the heart rate. The goal of this project is to develop an algorithm to detect these changes for pulse recognition which can be easily used by any individual. With the aid of Eulerian Video Magnification, we can determine a person's pulse simply from video of face or wrist [7]

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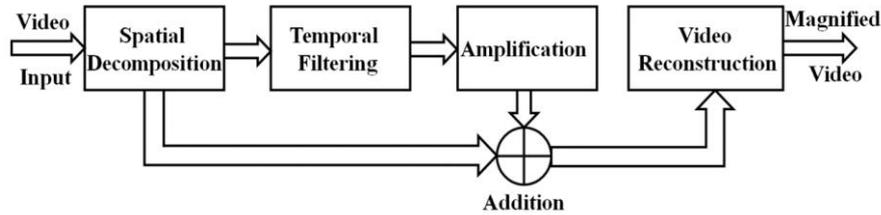held at M. E. S. College of Engineering, Pune 11–12, February 2016

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Fig.3 Eulerian video Magnification block diagram

Fig.3 shows its block diagram. It reveals low amplitude variation in a given temporal frequency band of interest. For this application, temporal filtering needs to be applied to lower spatial frequencies. Temporal processing is used to extract invisible signals or motions which need to be amplified. Here, in this case, localized spatial pooling and bandpass filtering is done to extract and reveal visually the signal corresponding to the pulse. This allows us to amplify and visualize the pulse signal at each location on the face [6].

III. METHODOLOGY

The subject was placed at a distance of 1 meter away from the webcam with bright light as the source of illumination. As the video was being recorded, the heart rate of the subject was noted down manually using a heart rate monitor for every 10 sec interval.

In this method we first decompose the video sequence into different spatial frequency bands i.e. Laplacian or Gaussian pyramids [1].This is called as multi scale analysis. The different bands may have varying SNRs and to some of the bands the linear magnification cannot be applied [4]. In order to minimize the artifacts, some bands are not magnified. The spatial filtering may be a done by a laplacian filter to increases the signal to noise ratio. The size of the spatial filter should be properly estimated. Next stage is the temporal filtering. A band pass filter like butterworth is applied to acquire the required frequency band, by considering the time series corresponding to the value of each pixel.
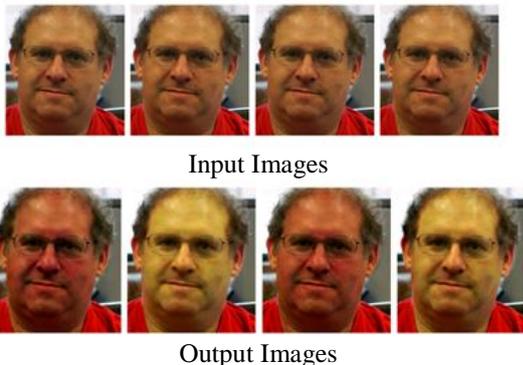

Input Images

Output Images
Fig.4 Eulerian Magnified Image

A more noise free result can be obtained by using a narrow filter especially to amplify the color variations.

Eg. Low order IIR filter. The next step deals with selection of an amplification factor α and a spatial frequency cut-off beyond which an attenuated version of α is used. A large amplification factor of around 100 and a spatial cut off of around 1000 is preferred. After amplification, it is added to the original signal and the pyramid is collapsed to reconstruct the output Eulerian Magnified Video. Fig. 4 shows magnified frames where there is visible color changes.

Heart Rate Extraction:

In order to detect pulse accurately from Eulerian magnified video several steps need to be implemented as shown in Fig 4.

Firstly we need detect the face using [3] to reduce the background noise effect on the results.
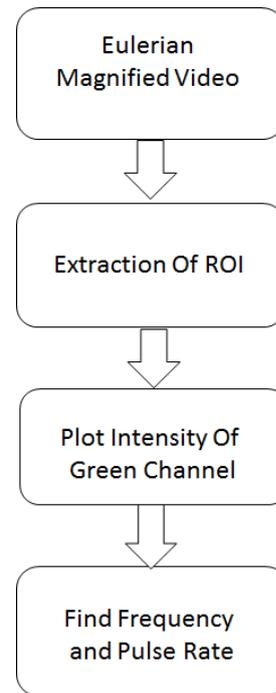

Fig.5 Heart rate extraction flow chart using RGB component

Heart rate of the subject can be extracted from the Eulerian magnified video constructed by taking the face video of the subject in proper luminance. The first step in finding the heart rate is to extract the region of interest as shown in figure. The ROI can be from any

region of the face where the changes are clear e.g. forehead or cheek. The mean value of intensity of all the pixels in that area is plotted against time. The pixel values (red, green, and blue channels) of the facial area of the magnified video. The pixel values within a region of interest (ROI) were then averaged for each frame. This spatial averaging was found to significantly increase signal-to-noise ratio.

The green channel features a stronger cardiac signal as compared to the red and blue channels. This is a strong evidence that the signal is due to variations in the blood volume, because hemoglobin absorbs green light better than red and blue light. Hence, we plot the only the green channel intensity values which approximately represents a sine wave.

Now the aim is to find the frequency of this wave obtained. So we find the location of peaks and the distance between them. According to frame rate, calculate the distance in terms of time. The average of all the distances gives the time period T of the wave which in turn will give the frequency. As heart rate is measured in beats per minute (bpm), multiply the result by 60.

IV.RESULTS

The results of this algorithm which works fairly well when the video is Eulerian magnified as well as cropped so that the video is zoomed in on a cheek or forehead. The tiny patches of skin are good indicators for the program as long as shadows and glares don't interfere. Fig.6 shows magnified frames obtained after performing the above steps.
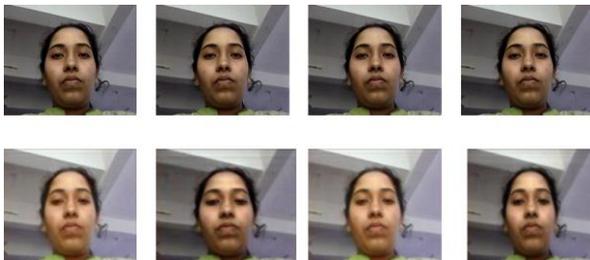

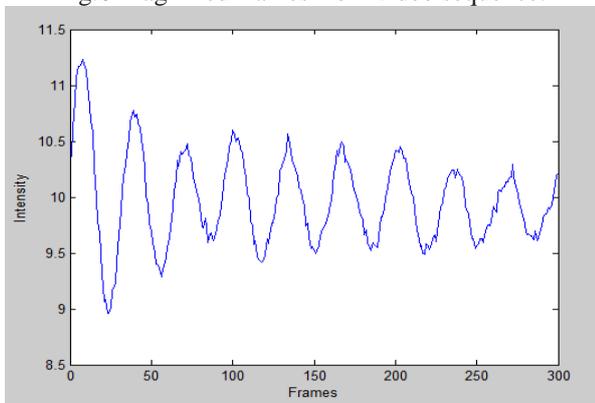Fig.6 Magnified frames from video sequence.

Fig.7 Plot of green channel pixel variations to obtain heart rate

Fig.7 shows plot used to obtain heart rate. The number of peaks was found in each 10 second window and thus the heart rate was calculated. The obtained heart rate from this method is verified with actual heart rate measured with instrument. We have verified the heart rate of 3 different age groups shown in below table.

Age	Samples	Estimated heart rate	Actual heart rate	Accuracy
4 -10 Years	10	92 bpm	95 bpm	96.84%
20 – 40 Years	25-30	68 bpm	70 bpm	97.14%
60-75 Years	20-25	72 bpm	73 bpm	98.63%

Table 1: Verification of heart rate

Sensitivity to Noise: The amplitude variation of the signal of interest is often much smaller than the noise inherent in the video. In such cases direct enhancement of the pixel values will not reveal the desired signal. Spatial filtering can be used to enhance these subtle signals. However, if the spatial filter applied is not large enough, the signal of interest will not be revealed. Assuming that the noise is zero-mean white and wide-sense stationary with respect to space, it can be shown that spatial low pass filtering reduces the variance of the noise according to the area of the low pass filter. In order to boost the power of a specific signal, e.g. the pulse signal in the face, we use the spatial characteristics of the signal to estimate the spatial filter size.

One major restriction is that the program is limited by frame rate. This limitation on how precise the estimation can get is called round off error. Since half frames cannot be calculated the algorithm must go to the nearest frame causing some error in pulse. Another big disadvantage to the algorithm is the necessity for both Eulerian magnification method as well as cropping. The algorithm has been tested using videos that have either not been magnified as well as videos that have not been cropped and the program may sometimes get a lucky guess but it has a much higher percent error. Also, light and shadows can cause misreading because it can hinder the hue, saturation and intensity values. Finally, the program is limited by the camera that takes the video. If the video is blurry background noise can get in the way of the algorithm. If a camera has a slow frame rate then the frame distance error might not be far off but the pulse will fluctuate greatly.

V. CONCLUSION

Through this paper, we have shown that proper reliable and accurate heart rate measurement can be done without any physical interference. This greatly helps in detection of heart rate in various situations including personal health care for an individual. Although there are certain limitations like luminance effect and blurry background, low frame rate, etc., it can be overcome up to an acceptable extent by improving its efficiency. With

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the ease of access about an individual's personal health that our method will provide to the average consumer, it is our hope that the average person will become more informed and take a more active role in their own health. Our method may lead the way to individual's checking their hearts as often as they would check their cell phone for a message. A possible concern of this technology is that with the elimination of physical contact and the added power of measuring heart rate from a distance. This may open up the door to being secretly scanned by unauthorized parties who wish to obtain our own personal health information for unethical reasons.

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