A Non Contact Method for Measuring Heart Rate using a Webcam

Biju V.G., Anith Mohan, Summayya M

Greeshma Rosemary Vilfred, Janita Alice Starina, Ajay Soman

Associate Professor, Assistant Professor, UG Scholars, ECE Dept., CUSAT
College of Engineering Munnar, Munnar, Kerala-685612, India

Abstract — *this paper proposes a webcam based, robust, low-cost method of measuring heart rate. By applying independent component analysis on the RGB colour channels in the video recordings, the blood volume pulse from the facial regions is extracted. Heart rate (HR) was then subsequently quantified and compared with corresponding measurements using FDA approved finger blood volume pulse sensor and obtained high accuracy. This technology has significant potential for advancing personal health care monitoring.*

Keywords — *Autonomic nervous system, blood volume pulse (BVP), independent component analysis (ICA), noncontact, respiration.*

I. INTRODUCTION

One of the most frequent examinations performed in health care monitoring is cardiac pulse measurement. Different methods of contact measurement of a heart rate are Laser Doppler [1], microwave Doppler radar [2], and thermal imaging [3]. Some of the common drawback of the aforementioned proposals is that the systems are expensive and require specialists' hardware. Photoplethysmography (PPG) [4] utilizes changes of the optical properties of a selected skin area involved by pulsating blood contents. Changes of the light intensity reflected from the skin correspond to a volume of tissue blood flow. Moreover, it has been proved that pulse measurement from human face is also possible using daylight as the illumination source. The method is based on blind source separation of the colour channels into independent components. Limitations of previous proposals are overcome through the proposed method which provides a technique for monitoring patients physiological signals without any direct physical contact so as to improve access to and enhancing the delivery of primary health. Independent Component Analysis (ICA) [5] technique is utilized for analysing independent signals from a set of observations that are composed of linear mixtures of the underlying sources for the computation of HR [6]. The timing of the cardiovascular event is indicated by the volumetric changes in the facial blood vessels the change the path length of the reflected light during the cardiac cycle.

The theory behind the project is explained in section II. Methodology and related information makes section III. Section IV contains conclusion and project ends with results and discussion in section V.

II. THEORY

RGB colour sensors are used to pick up a mixture of plethysmographic signals along with other sources of fluctuations of light from the recorded video. Each sensor records a mixture of original signals with slightly different weights. The observed signals from the RGB colour sensors are denoted by y_1 (t), y_2 (t), and y_3 (t), respectively, which are the amplitudes of the recorded signals at time point t. We assume three underlying source signals, represented by $x_1(t)$, $x_2(t)$ and $x_3(t)$. The ICA model assumes that the observed signals are linear mixtures of the sources, i.e.

$$y(t) = \boldsymbol{A}x(t) \qquad (1)$$

where the column vectors y(t) = $[y_1(t), y_2(t), y_3(t)]$T, x(t) = $[x_1(t), x_2(t), x_3(t)]$T, and the square 3×3 matrix A contains the mixture coefficients a_{ij}. Independent component analysis (ICA) is a technique for uncovering independent signals from set of observations that are composed of linear mixtures of signals. The objective of ICA is to find a demixing matrix W, i.e. an approximation of the inverse of the original mixing matrix A whose output

$$x(t) = \boldsymbol{W}y(t) \qquad (2)$$

III. METHODOLOGY

A. *Experimental Setup*

The experiments were conducted indoors and with a varying amount of ambient sunlight as the only source of illumination. Participants were seated at a table in front of a laptop at a distance of approximately 0.5 m from the built-in webcam [see

Fig.1]. During the experiment, participants were asked to keep still, breathe spontaneously, and face the webcam while their video was recorded for one minute. All videos were recorded in colour format at 20 frames per second (fps) with pixel resolution of 640 × 480 and saved in AVI format on the laptop.

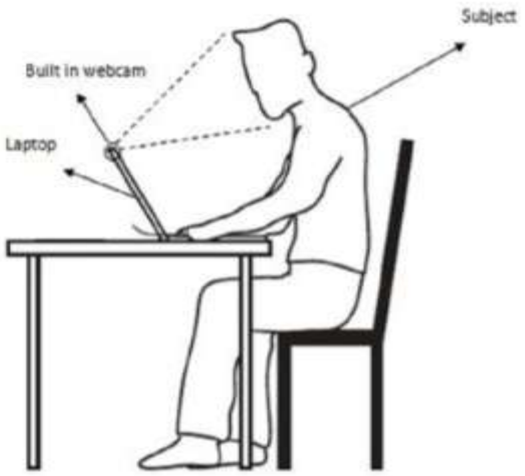

Fig.1 Experimental setup

B. Recovery of video from webcam

Open Computer Vision library is utilised to detect face location of each frame of the video recording using a boosted cascade classifier. The viola-jones algorithm returned the *x* and *y* coordinates along with the height and width that defines a box around the face. The bounding box around the face gives the Region of Interest (ROI) [7][see Fig.2(a)]. The ROI was then separated into the three RGB channels[see Fig.2(b)] and averaged all pixels in the ROI to get a red, blue and green measurement point for each frame and form the raw signals y_1(t), y_2(t), and y_3(t) respectively[seeFig.2(c)].

Fig. 2(a)

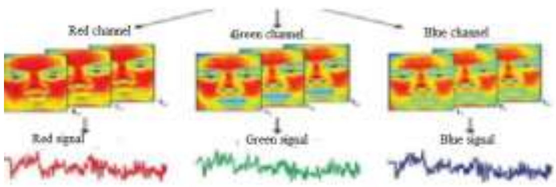

Fig. 2(b)

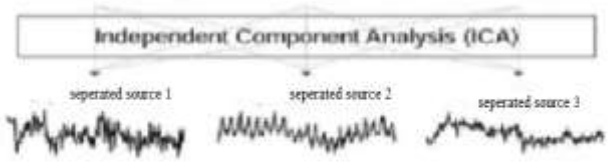

Fig. 2(c)

Fig. 2: (a) Face within the first video frame is automatically detected to locate the ROI.
(b) ROI is decomposed into red, green, and blue channels for each frame and spatially averaged to form the raw signals
(c)After the raw signals are de-trended and normalized, ICA is applied to separate three independent sources.

C. Normalisation and then pass the normalised value matrix to Jade R

The mean of red, green and blue planes for each frame is calculated. After that take the average value of the mean of each plane . Then obtain the standard deviation of each component. After obtaining the standard deviation of each component calculate the normalized value using the given formula

$$\text{Norm} = \frac{(\text{sum} - \text{mean})}{\text{Std deviation}} \qquad (3)$$

The normalized raw traces are then decomposed into three independent source signals using ICA based on the Joint Approximate Diagonalization of Eigen matrices (JADE) algorithm [8]. In experiments, *JADE* is run as *B = JadeR (X,m)* where X be the normalised value and m varies in range of values. Jade selects the component having highest energy level and which is then selected for further analysis.

D. Power Spectrum Analysis and Calculating heart rate

The power spectrum [9] of a signal is the power of that signal at each frequency that it contains. Calculate the FFT of the signal X, transform to power, and generate frequency range according to the sampling rate Fs. A fast Fourier transform (FFT) is an algorithm to compute the discrete Fourier transform (DFT) and its inverse. Fourier analysis converts time (or space) to frequency (or wavenumber) and vice versa.

Set Frequency Limit- Set low frequency and High frequency limit for calculation [10]. Frequencies below low frequency limit (.9) and frequencies above high frequency limit (1.6) are not considered for processing. Plot power spectrum Set the axis to plot the Power Spectrum with frequency in X-axis and Power Spectrum in Y-axis. Find maximum power spectrum value and find frequency at that point. After plotting Frequency-Power spectrum, obtain the peak value of the Spectrum along with its index. Frequency value at that index is taken as the maximum frequency.

Heart rate = maxfrequency × 60 of R,G,B. Take average beats per minute and display.

IV. RESULTS AND DISCUSSIONS

Using the proposed technique, we extracted the heart rate from the webcam recordings via ICA and compared with an FDA approved finger blood volume pulse sensor and achieved high accuracy. We applied this technique to perform heart measurement of 10 participants. A typical example of recovered heart rate measurement of two participants is shown in Fig. 3(a) and 3(b). It is possible that linearity assumed by ICA is not representative of the true underlying mixture in the signals given that the reflected light intensity varies non linearly with distance travelled through a facial tissue according to the Beer-Lambert law. The methodology we described in this paper can be implemented in home environment. In this study we did not address how the proposed method will fare in low lighting, but our experiments where conducted different times of day with different degrees of ambient illumination. The performance of our technique did not vary significantly within this range of luminance, but the SNR of the recovered signal decreases in dim light.

V. CONCLUSION

The project illustrates an innovative approach to monitor health, based on image processing. This interface is intended to provide a convenient means for people to track their daily health with minimal effort. The advancement in medical technology can prove beneficial to many people. The proposed technology is helpful because many times, sensing equipment is uncomfortable to the body. It could also help doctors keep better track of their patients without costly hospital visits. The most important factor of this new technology is it can be used anytime anywhere.

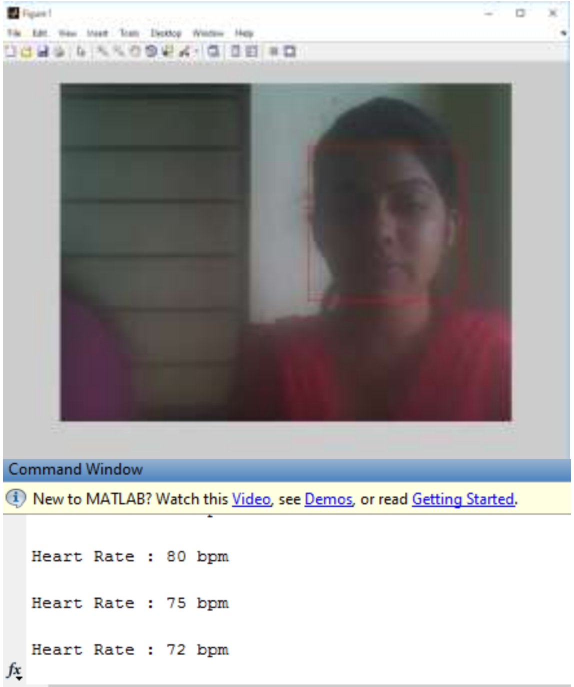

Fig. 3(a)

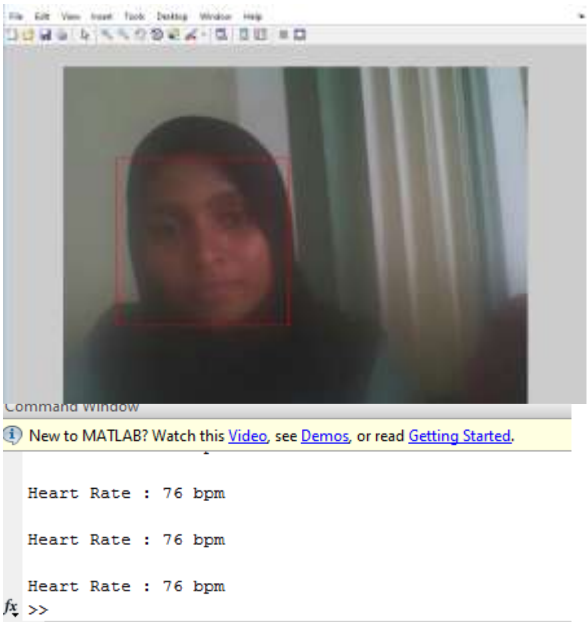

Fig. 3(b)

ACKNOWLEDGMENT

We express our sincere gratitude to our guides Mr. Biju V.G. Associate Professor and Mr. Anith Mohan, Assistant Professor of College of Engineering Munnar, Kerala, India for their guidance and supervision throughout the preparation of the paper. We especially thank our parents for their support, love and care for preparing us to complete our paper work.

REFERENCES

[1] S. S. Ulyanov and V. V. Tuchin, "Pulse-wave monitoring by means of focused laser beams scattered by skin surface and membranes," in OE/LASE'93: *Optics, Electro-Optics, & Laser Applications in Science& Engineering*. International Society for Optics and Photonics, 1993, pp. 160–167.

[2] E. Greneker*, "Radar sensing of heartbeat and respiration at a distance with applications of the technology," in Radar 97* (Conf. Publ. No. 449). IET, 1997, pp. 150–154.

[3] M.Garbey, N.Sun,A.Merla, and I.Pavlidis, "Contact-free measurement of cardiac pulse based on the analysis of thermal imagery," *Biomedical Engineering, IEEE Transactions on*, vol. 54, no. 8, pp. 1418–1426, 2007.

[4] J. Allen, *"Photoplethysmography and its application in clinical physiological measurement," Physiological measurement*, vol. 28, no. 3, p. R1, 2007.

[5] J.-F. Cardoso, *"High-order contrasts for independent component analysis," Neural computation*, vol. 11, no. 1, pp. 157–192, 1999.

[6] M. Malik, *"Heart rate variability," Annals of Noninvasive Electrocardiology*, vol. 1, no. 2, pp. 151–181, 1996.

[7] R.-L. Hsu, M. Abdel-Mottaleb, and A. K. Jain, "Face detection in color images*," Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 24, no. 5, pp. 696–706, 2002.

[8] D. N. Rutledge and D. J.-R. Bouveresse, *"Independent components analysis with the jade algorithm," TrAC Trends in Analytical Chemistry*, vol. 50, pp. 22–32, 2013.

[9] S. Akselrod, D. Gordon, F. A. Ubel, D. C. Shannon, A. Berger, and R. J. Cohen*, "Power spectrum analysis of heart rate fluctuation: a quantitative probe of beat-to-beat cardiovascular control," science*,vol.213,no.4504, pp. 220–222, 1981

[10] M. Malik, T. Farrell, T. Cripps, and A. Camm*, "Heart rate variability in relation to prognosis after myocardial infarction: selection of optimal processing techniques," European heart journal*, vol. 10, no. 12, pp. 1060–1074, 1989.