A Non Invasive Heart Rate Measurement System for Multiple People in the Presence of Motion and Varying Illumination

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ABSTRACT

A real time non-invasive heart rate (HR) measurement system for multiple people in an image has been proposed in this paper. The data has been gathered using a webcam with different distances with the subjects under varying illumination conditions. The effect of motion of the subjects on HR measurement is also observed. The data is gathered from the face and cheeks are selected as the region of interest (ROI). RGB color model is used for processing. Fast Fourier transform is used to detect the peak frequency after band pass filtering. The green channel of RGB color model gives best HR measurement. The minimum percentage error of 3.1% is achieved in the presence of slow movement and multiple persons at the relative distance of 100 cm.

KEYWORDS

Fourier Transform, Heart Rate, Non-invasive, Real Time, RGB Color Model

INTRODUCTION

Heat rate is measured by the number of heartbeats per unit of time, and is expressed as beat per minute (bpm). Conventionally, heart rate can be measured by Electrocardiography (ECG) or pulse oximetry based on photoplethysmography (PPG) (Hertzman, 1938). Though reliable and inexpensive, the conventional techniques use contact based devices that may result in discomfort when placed or removed. Repeated measurements have a negative impact on well-being and development of infants (Chen et al, 2010). Any device that has some contact may not be suitable for elderly, infants, burn victims and/or people with mental disorders.

The non-invasive heart rate measurement system uses a sequence of images of the human skin for optimal measurement of the HR. This measurement technique is based on the property of reflectivity of the blood. The variation in the reflectance of light is proportional to the volume of blood in the arteries. This variation cannot be observed with the naked eye however, imaging devices can be used to capture the photoplethysmography (PPG) from those variations (Aarts et al, 2013). Kranjec et al. presented a review of techniques used for contact-free HR measurement (Kranjec et al, 2013).
The techniques included Doppler radar, vibrocardiography, thermal imaging, RGB camera, and HR measurement from speech. Many studies have suggested HR measurement using smart phone camera, which may have the advantage of remote observation and patient management (Kwon et al, 2012). The heart rate measurement using imaging device requires certain constraints to be met for consistency. Such constraints include relative position and distance of the subject and camera, and consistent illumination. Sandercock et. al., suggested that reliability of the techniques changes with change in protocols, requiring optimal conditions (Sandercock et al, 2005).

Poh et al. used face as region of interest (ROI), RGB color model for processing the images and independent component analysis (ICA) and Fourier transform to predict HR (Poh et al, 2011). However, it is interesting to note that the eyebrows and beard do not contribute to the measurement, hence if these are not excluded from the face image, the accuracy of the system will be compromised. Hung et al. proposed a multiple camera system for identification of HR related features (Hung et al, 2013). They used neural network based classifier to identify the skin. They used multiple camera to address the problem of the subject mobility. However, it resulted in a complex system for remote use. Another research suggests detection of atrial fibrillation by detecting the skin color variations from facial video (Couderc Couderc et al, 2015). They assume that the patient head is not moving. Datcu et al. compared different facial regions for their suitability for HR measurement and suggested forehead and cheeks to be most suitable (Datcu et al, 2013). Another recent research uses different color channels for contact free HR measurement, and RGB color model was found to be most efficient (Nisar et al, 2015). In this work, HR measurement is implemented for single and multiple subjects using face detection and tracking. The effect of distance between subjects and camera, and subject motion on accuracy was assessed under different illumination conditions.

METHODOLOGY

The experimental setup for this research consists of a web camera, OMRON Blood pressure monitor and POLAR heart rate monitor with chest strap. The video was recorded at a resolution of 640 × 480 pixels and frame rate of 30 fps. It was saved in AVI format without compression. The POLAR heart rate monitor collected the data simultaneously with the video recording. The data was collected from 3 volunteers for 3 different cases. Each case was conducted on 2 different subjects. During the measurement, the distance of the subjects from the webcam was varied to see its effect on the measurement. The measurements were performed indoor with illumination sources such as fluorescent light and sunlight. The flow chart for the HR detection system is shown in the Figure 1 (Nisar et al, 2016).

Face Detection and Tracking

Face detection and tracking was performed for two ROIs by Viola Jones techniques using MATLAB function (Nisar et al, 2016). The first ROI was the whole face whereas the second ROI was cheek. The second ROI was segmented according to the coordinates of the cheeks, disallowing the participant to turn his face. Since the heart rate is monitored continuously, the face detection will be done for every frame of the video.

To segment the cheeks, the coordinates of the corresponding region were derived from the box created by Viola Jones face detector. A box is characterized by four arguments. The first two represent the coordinates of the origin located at the top left of the big box as shows in Figure 2. The last two indicate the width for x and y axis. Let X, Y be the coordinates of the origin of the Viola Jones box and W the width of the box along both x and y axis. The boxes for the left and right cheeks can be respectively characterized as:

\[(X_L, Y_L, W_L, W_L) = (X+0.1W, Y+0.5W, 0.25W, 0.25W)\]  (1)