Efficient Approach for Measuring Heart Pulse from Real Time Facial RGB Color Videos

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***Abstract*— The heart, the vital organ of the human body, needs to function with proper care and therefore it is important to monitor. Detecting Heart Rate (HR) often requires costly equipment which are complex especially with sensors. Various methods are defined over the years to measure heart rate. One of them being a noncontact method of measuring heart rate using remote photoplethysmography (rPPG). This paper presents a working solution on the live video i.e., in real-time. A set of rectangles are established around the face for detection along with object detection, which are later used in the pipeline of color variations. The mean of the colors (RGB) in the Region of Interest (ROI) selected on the face (forehead region). Thus, signal is obtained from the heart rate frequency by signal processing method. This paper discusses the reimplementation of one such approach that uses fast fourier transform (FFT). Researchers can now refer to the reviewed and classified algorithms as a starting point to improve and increase the robustness of the experiment.**

Keywords*— *Heart Rate, non-contact, Fast Fourier Transform, camera-based, photoplethysmography.

I. Introduction

Heart, being the vital organ in a human body is subjected to many risks. A person's heart rate (HR) can be a result of their lifestyle such as health, physical exercises, anxiety, stress and more. The above-mentioned factors differ from each person. General circumstances to measure Heart rate would be in a hospital environment. In the beginning of monitoring of heart rate, physical touch was required for equipment to work and precisely generate results of the patients [1].

The cardiac pulse is typically measured in clinical settings using electrocardiogram (ECG), which required them to wear on their bodies which proved to abrasive and uncomfortable. Later years, the method to measure or monitor heart rate measurement has changed, which resulted in using sensors that may be worn on the fingertip or earlobe. Hence, after moving to the adaptation of sensors, one of the inferences to note is that they were discomforting to the wearer. Furthermore, in acknowledging such situations over the past few decades, a non-contact means of detecting Heart rate was developed. Such a method would be very beneficial. Noncontact heart rate measure through a simple camera either on laptop, computer or phone. Interest in maintaining the fitness of the body has made people health conscious and resulting technology trends and growth led to such experiments [2-3].

Few earlier studies have shown that heart rate can be calculated using a person's face in a video. So, our research can be simple stated as reimplementation of one such approach that uses fast fourier transform on mean pixels within a region of interest (ROI). Then, we explore the head movement of the subject and bound their face and forehead region in a box, to measure the heart rate more accurately [4-5].

A measured heart rate is obtained from the number of contractions per minute as a volumetric measurement (plethysmogram). Moreover, photoplethysmogram (PPG) application which exists in smart watches today and other fitness tracking products proven to have some sought of physical touch on a wearer which is discomforting. Many researchers have been trying to perfect the application by any means necessary [6]. The studied technique uses a color-based model RGB imaging to receive a signal by placing the subject few meters from the camera. Later, it was slowly taking the shape and named as remote photoplethysmography (rPPG). The main aim of our research is to observe, study and lend a hand in such important applications which makes life easier and helpful to continue in the growing years. And heart rate monitoring based on head movements which are periodic is another observable phenomenon effected by the cardiac cycle and thus allowing practitioners to obtain HR through monitoring from an estimated rPPG signal [7-8].

Such application was put forward in 2008 [7], nearly more than two decades and still the observation finds to attract attention and constantly trying to perfect the application. To my dismay, earlier research papers did not discuss every aspect in detail. The basic pipeline which was used for the execution is the same. As stated earlier, our contribution to this topic-

1. Is to provide an outline of previously organized research in medical sciences.

2. Is to label studies by preferred algorithm and contributions to the field. We chose to use this method- rPPG because it is the most frequently used (~50%) and more approachable to novice accomplices.

The reviewed research relating to rPPG that used low-cost process, was only targeted because, much of the work is related to the thought or idea we had earlier. Recording equipment is of commercial grade. Included only those in regard whose goal was to obtain HRM using videos or live capture of subject faces. And from that standpoint, proceeding towards the details regarding the implementation of our research.

The remaining paper is split into various sections which briefly describe the pipeline of our project. As the research is mostly based on few prior papers. Extensive developments are not listed but considered and will surely be acknowledged in the development of the paper later. Section II details the methodology, section III deals with approach, section IV discusses the setup and equipment used. Finally, section V is dealt with conclusion of the paper.

II. METHODOLOGY

The method exploited in the research regarding the rPPG is related to the cardiac cycle very closely. Each cycle being periodic will show affects both on the facial skin and mechanical head movement, which enables researchers to calculate HR.

The connection between the light and human tissue on the foreskin of a person's head is complex. When the application is all about low-cost and easy accessibility, certain aspects of the experiment should hold viable for a proper conduct of the research. This has shown the reflection of light is dependent on many factors present in the environment and among them, change in blood volume and blood vessel [9-10] movement. Present day research has shown that ambient light is sufficient to acquire a plethysmographic signal [11]. All the above-mentioned changes in the region of the face, are not easy to track and difficult to be visible by a naked human eye. So, to detect such phenomena the implementation of the image processing algorithms is necessary. These are used for selecting the region of interest and observing the change in intensities of the pixels located in the region. By calculating the mean of the intensities of the pixel and extracting the frequencies using FFT would provide us with a clear peak of values which the represent the heart beats. To achieve the primary goal of this project, the implementation of the ROI was carried in Jupyter notebook and other related python libraries- mainly OpenCV.

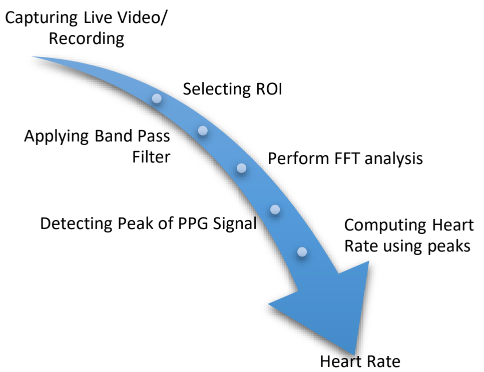

Figure 1. Determining Heart Rate

A. Detecting Faces

Face detection is not the important aspect of the research, so we are not choosing the best method available but one that is readily available and is implemented on the hardware and mobile devices for convenience's sake. The method for face detection is using Haar cascades, which has been proven effective and proposed by Michael Jones and Paul Viola in their paper [12]. Creating a haar cascade filter is complex but effective in the later end. Various objects can be focused and detected by training the machine learning model with two sets of images- positive and negative images. The positive set contains the features we want our filter to detect and focus while the negative contains all the unwanted data which makes the model distinguishable and helps in identifying the object. Viola-Jones proposal has stated several key-features, such as:

1. *Integral Image*s are used as an alternative to the pixel values the haar feature captures.

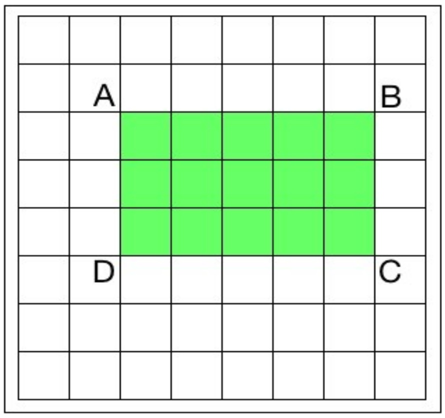

Fig. 2. Integral Images

2. *Haar Features*: Different rectangular sections within the image of the subject.

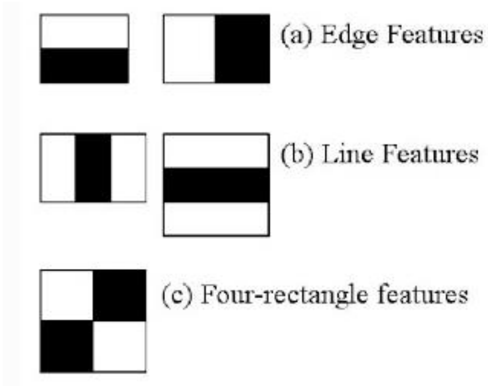

Fig. 3. Haar Cascade Features

3. *AdaBoost Algorithm*: optimum characteristics are selected, as this algorithm excels in binary classification.

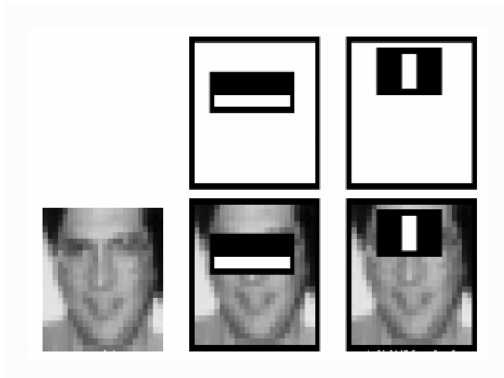

Fig. 4. Achieved through AdaBoost

4. *Cascade Filter*: to focus on the computing process of many positive ones possible, the filter negates the images which does not match the intended results.

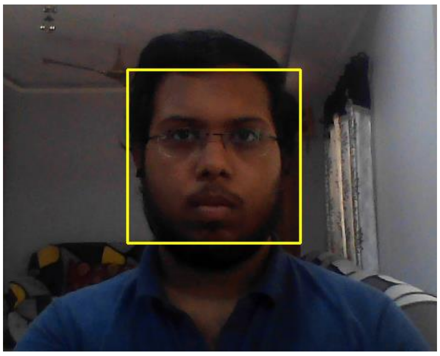

Fig. 5. Detecting Faces

B. *Selecting ROI*

The intermediary part of the process of determining heart rate. The portion (ROI) of the main image, to be used during the computational process, selected on a specific criterion. As discussed earlier, the skin color variation observed on the forehead is the best and optimal region to observe this phenomenon. Thus, a rectangular box enclosing on the ROI adapts to the changes depending on the distance between the camera and the subject. ROI is applied only to the frames where haar cascade filter detects the face of the subject. The enclosing is a significant way of making the observers understand the working of the process. Now, evaluating the mean of the pixels in the forehead portion and select maximum or peak of generated values to obtain a clear signal.

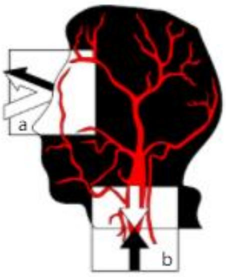

Fig. 6. Phenomenon explained in rPPG [13]

C. *Tracking Objects in Image*

Two options can be implemented to detect a face,

1. Detecting face for respective frame.
2. Face Tracking for individual frames using face detection algorithm.

Applied first procedure for the subject's face. Turns out there is another way which is quite [14] faster. The reason being, at the time of implementation, the method followed was not quite influenced in many studies and performed the experiment to the best of abilities.

D. *Heart Rate Measurement*

Most vital process of the research is studying heart rate. According to the information gathered from above sections, start by implementing the Fast Fourier Transform (FFT) for last 150 frames of the signal acquired from preceding frame. Heart beats are in the range of 35 to 195 beats per minute. The heart rate measurement translates this to a frequency between 1-3 Hertz.

Frequency filtering is applied to the false readings. The filter specifically used is a bandpass filter, used to transmit signals in a certain band of frequencies and block signals of lower and higher range. Same is observed in a television or radio by tuning for a desired frequency. The desired band is centered around a frequency. And finally narrow it down to finding out the heart rate of the subject.

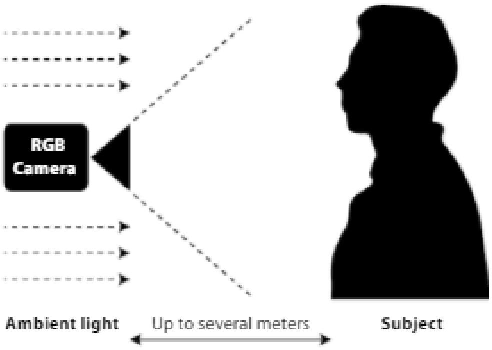

Fig. 7. Setup during rPPG application in HR measurement [13]

III. Approach

A lot of various sources define the process of calculating the heart rate. After studying different opinions on such study has opened many possibilities and areas to explore. To start with, the programming mainly involved building a gaussian like surface around the frame, just like in physics where different surfaces are built around objects. Every picture, live video or recordings are all read in the form of arrays in python.

1. During the gaussian phase, the frames are reduced in dimension and stored away for later use.
2. Define the parameters for the dimensions of the frame.
3. Define color magnification parameters.
4. Now, we define the parameters such as the thickness, font-color, font-scale and few others.
5. Initialize this gaussian frame we have built for the specified frequencies we are targeting.
6. The band pass filter is applied to the frequencies are targeted.
7. Most important parameters are for the heart rate for determining the frequency.
8. Reconstructing the frame by increasing the dimension of the frame, this is mainly done to aid with the computational process of the research.
9. Another helping hand function in this process would be to detect faces using haar cascade.

The above mentioned are to clarify the process we established for the research. A profound knowledge of different areas of interest will surely make all the change. In addition to the points above, with keeping in mind that it is low-cost and home-made computational process, we are very much limited by the equipment. But, to the best of our abilities we were able to design a process which soon be developed and adapted in industries.

It is fascinating to know from the previous studies that provide many ideas, methods to execute such experiments. With focusing on the idea, we had at the beginning, were able to learn and maintain the integrity for which the research stands.

Then, as stated earlier, convert the color image to grayscale mainly to decrease the computational process for various reasons and select the ROI based on the rectangle enclosing our face. Remember the ROI is less and based on the position of our forehead. Somewhat live tracking of motion of the face to aid us in determining the signal.

The function (FFT) commonly used for frequency analysis converts the time into frequency of the obtained signal. Being a better version of Discrete Fourier Transform (DFT), it can be applied when the number of specimens is of power two [15-16].

$$x_n = \frac{1}{N}\sum_{1=1}^{N-1} X_k \cdot e^{2i\Pi kn/N}, n \in Z$$

x_n is the discrete-time varying signal with a period N. For the PPG signal determination, FFT is computed and analyzed. Once the frequency of the signal is obtained from the spectrum, heart rate measurement is given by,

$$Heart\ Rate = frequency\ (f_h) * 60$$

A. Peak Detection

Individual peaks in the spectrum are used for extracting more information such as heart rate variability. To obtain a refined signal from peak detection, we use a cubic spline interpolation [17-19]. This is often used when the time frame or the data we have or generated is small. The points can then be recognized using a moving section, as they represent the maxima.

$$Heart\ Rate = f_h * [(Number\ of\ peaks/Time)]\ bpm$$

More elaborated formula for the understanding of measuring heart rate. This approach is selected to provide calirty in determining the signal.

IV. Setup

During development, the process and trials were performed on the hardware mentioned:

- Processor: Intel^R Core^{TM} i5 7200U CPU @2.50GHz
- RAM: 16.00 GB
- 720p laptop-camera FHD

Now, computing the average the pixels present only in ROI. By juxtaposing the results acquired for different subjects having slightly visible difference between skin tone. All the observations are noted in the morning and in a well-lit environment for better result. None of the subjects suffered from any skin conditions.

TABLE I. Experiment Details

Subject	Features		
	Age	*Skin Tone*	*Gender*
1	21	Brown Medium	Male
2	21	Brown Medium	Male

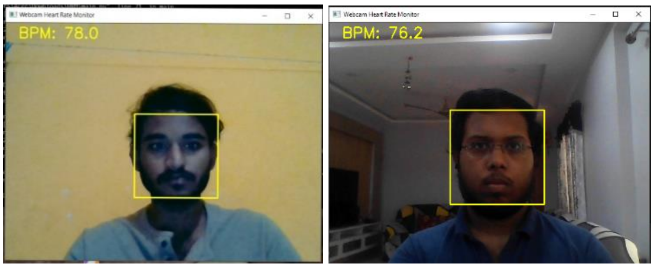

Fig. 8. Shows subject 1 & 2 during the test:

Figure Labels: Performing tests on Subject 1 and Subject 2 having similar skin tone.

While calculating the HR, tests are done later in parallel with another application to certify the accuracy of the measurement. Error variation detected from 1.0 – 5.0 %, but it is hard to detect errors in this process, as these can be a result of the intrinsic ones. The tests performed on the subjects belong to the Indian subcontinent. One more study suggests that the heart rate can be affected by fitness. The more obese a person is, the higher the chances of heart rate rising. Because the cardiac cycle maintained by the veins in our forehead upholds more stress in flowing the blood. When the mean is observed between the two subjects, they vary. And this variation is to be note on the fitness levels and no other factors.

TABLE II. Heart Rate Tests

Number	Experiment Results		
	Subject	*Observations (5)*	*Error (%)*
1	Person A	76.2	~ 1.2
		75.6	
		73.8	
		77.4	
		78.0	
2	Person B	85.2	~ 4.2
		77.4	
		85.8	
		80.4	
		76.2	

V. Conclusion

A real time noncontact-based heart rate method is described in this paper using facial video of a subject, which is easy to implement, cost effective and comfortable in real time applications. The main idea is to determine heart rate using from the color variation in the foreskin of a subject who is completely still or slightly moving, though any of those factors will not affect the process. With sufficient ambient light, the experiment works. Comparison of our experiment is done with other applications to strengthen our case of using rPPG. Though many variations observed in the procedure, the results are similar, precise and notable. The noncontact technology in the last two decades has been noted by many scholars and many improvements had taken place. The most promising sector for such applications to work would be medical, road safety, security. Also, to increase the accuracy of the application would involve only making more observation in different scenarios and other verifying systems. Creating a real-time, multi parameter application with different technological improvements will be the subject of future work.

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