# Photoplethysmography On Smart Phone Using Savitzky-Golay Filter

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*Abstract* — **Measurement of Heart rate using Smartphone is widely used by many people. There are some issues in measuring Heart rate such that the noise, distorted peaks. To overcome this issue the project proposes an algorithm using Savitzky-Golay filter which is more efficient than an algorithm using moving average filter. An algorithm considered the red channel of the video obtained from an application of video recording of the Smartphone.**

***Keywords – camera; Heart Rate; photoplethysmography; Smartphone .***

## I. INTRODUCTION

The smartphones built in camera and flash used for measuring the vital parameters. Optical video monitoring of the skin with a digital camera contains information related to the subtle color changes caused by the cardiac signal and can be seen to contain a pulsatile signal [1], [2]. Given illumination of the area with a white Light Emitting Diode(LED) mobile phone flash, this type of imaging described as replication photoplethysmographic (PPG) imaging.

Jonathan *et al*. showed the potential to extract the heart rate (HR) signal from a sequence of video images [2], [3], and Pelegris *et al*. compared HR measurements using a mobile phone with those made using a standard pulse oximeter and the measurement provided can be used as a tool for health coaching applications or effective telecare services aimed in enhancing the user's wellbeing [4].

An application currently exists on the android market to obtain HR using the optical video recordings [5]. The potential of monitoring the dynamics in the HR signal and extracting additional vital physiological factors from the optical recordings has not been fully discovered. It is known that the dynamics of the HR signal that can be captured by PPG contain information that can be used to detect such physiological conditions as atrial fibrillation, blood loss, and cardiac autonomic job [6]–[10].

Banitsas K. *et al*. [11] demonstrated how to extract heart beat rate information from capturing red channel of fingertip video of a user using the camera of a commercially available mobile phone which will enable to supply the users of the system with vital information and utilize interactive tools useful for personal health coaching and proposed to normalize signal using smooth differentiation. Then the number of peaks of the normalized signal is counted and divided by the length of the signal. The result of this operation multiplied with 60 is heart rate value.

Domenico Grimaldi *et al.* devoted red channel has similar characteristics for different models of the smartphones while the green and blue may vary dramatically. However, such information can be used to filter the wrong usage of the system, i.e. when the finger was not places correctly. The experimental results confirm the correctness and suitability of the proposed technique in respect to the oximeter [12].

The algorithm described in [13] proposes to filter signal with a moving average filter. Then filtered signal is split into windows of fixed length and for each window the signal is compared to sinusoidal form. If the signal matches a form, the heart rate is measured by determining the number of peaks and multiplying the peak count with the ratio of 60 to the window length. Because of it filtration reduces not only the amplitude of the noise but amplitude of the total signal. To cope with these issues we developed a new algorithm of the heart rate measuring.

The proposed system considered the HTC hero mobile which is used for taking a person's fingertip video for 20 seconds. The red and green channels of the video is processed using Savitzky-Golay filter which is used for reducing the nosie and has the band of interest between 40 to 230 beats per minute (BPM).

## II. METHODOLOGY

### A. *Photoplethysmography*

Photoplethysmography (PPG) is a non-invasive technique for detecting blood volume changes during a cardiac cycle at selected body locations. Clinical PPG applications range from monitoring of blood pressure, heart and respiration rate, blood oxygen saturation, to detection of peripheral vascular diseases. The technique functions by illuminating skin with penetrating optical radiation usually from a light emitting diode and

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detecting the transmitted signal in the case of transmission mode PPG, where the photodetector is positioned directly across from the light source, or the reflected signal, for the case of reflection mode PPG achieved by locating the photodetector next to the light source. Replacing the photodetector with a camera, the technique ceases to be limited to single-point measurement and PPG imaging is realized as shown in figure 1.

Figure 1. Smartphone's camera unit

Every heart beat creates a wave of blood that reach the capillaries in the tip of the finger; when the capillaries are full of blood less light can pass through them. So the changes in the amount and the colors of light which is passing through the finger can represent the changes in the shape of the pulse and its timing (the HR). Normally to take a photo or a video we need focus and some distance between the lens and the object. But we are focused in the amount of light, therefore there is no need of focus, and it is possible to cover the item lens and flash of the camera with the fingertip as shown in Figure 1.

During a systolic pulse when the capillaries are rich in blood, more light was absorbed by the blood, leading to a low reflective index and darker frame intensities. Likewise, during a diastolic pulse, most of the light was reflected leading to bright frames. The change in intensity of light passed through the finger creating an alternative pattern of waves. These changes in intensity with time were used to obtain the heart rate of an individual.

### B. *Data Collection*

Spontaneous finger color changes were recorded using a HTC Hero mobile phone. The left index finger was placed over the camera lens with the flash turned on as shown in figure 2. Subjects were instructed to rest a finger on the camera lens without pressing down with extra force, and to keep their finger quiet to reduce any motion artifacts. Videos were recorded with 820 × 400 pixel resolution at a sampling rate of 25 fps. The videos were converted to audio–video Interleave (AVI) format at 820 × 400 pixel resolution and 25 fps. All further analysis was performed on the AVI videos in Matlab R2013a (The Mathworks Inc.).

Figure 2. Finger placement over camera and flash

## III. SYSTEM MODELS

### A. *Video to frame conversion*

The block diagram of proposed system is shown in figure 3. The normal human heartbeat is between 60 and 200 beats per minute (bpm), depending on age, fitness state and the physical activity that the subject is doing. In the proposed system, the target signal can be found between 50 and 220 bpm, i.e. 0.833 and 3.667 Hz. The sampling frequency should be twice the highest value (7.667 Hz) to catch the whole range of heartbeat frequencies without aliasing. With the HTC camera, the video is recorded at 25 frames per second (fps). The video is converted into number of frames and the flowchart of conversion is shown is figure 4.

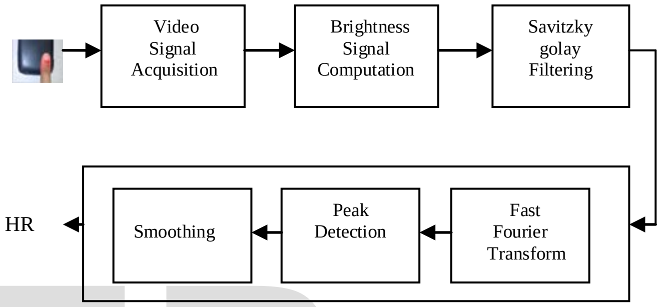


Figure 3. Block Diagram

### B. *Brightness signal computation*

Combined all pixels into a single average brightness value per frame and avoided the common image brightness computation, merging the red, green and blue planes in favor of a simple average of all the pixels in the red plane. The converted RGB frames are shown in figure 5.

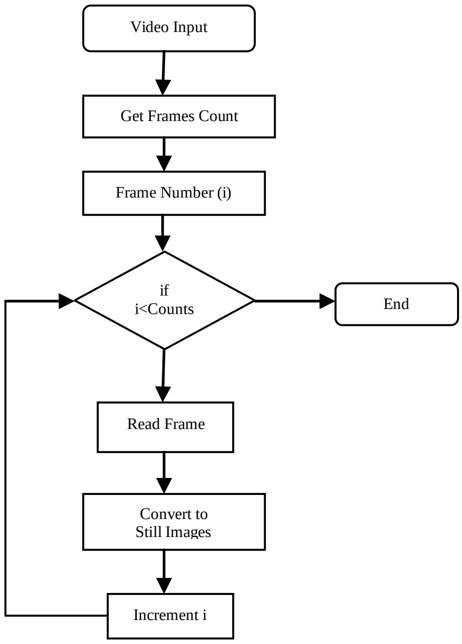

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Figure 4. Flow chart of video into frames conversion

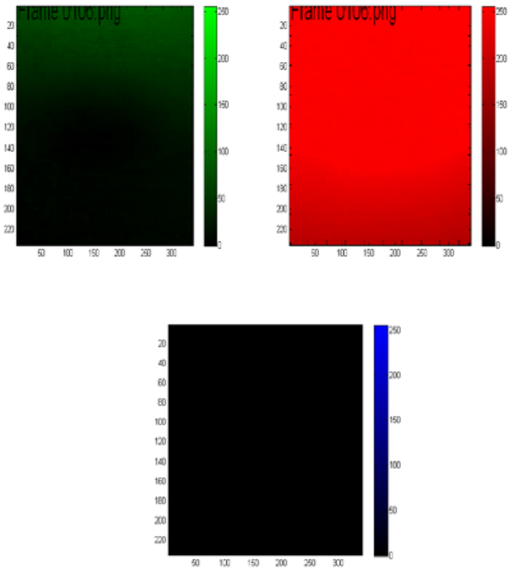

Figure 5. Red, Green and Blue Frames

This is computationally much inexpensive and gives very comparable results because almost all the frame energy is in the red plane.

As the frame size is constant over time and we are only attentive in the outline of the signal, not in its amplitude, we could even omit the division by the complete number of pixels but it will later help picturing the altered spectrum peaks.

## C. *Savitzky-Golay filtering*

After the signal acquisition, a Savitzky-Golay filter attenuates frequencies outside the interest band. This reduces the noise in afterward processing steps and makes the resultant heart rate signal smoother. The noise affecting the measurement comes from three sources basically:

- *Frame noise*: It initiates in the camera. By averaging every pixel for the brightness computation, we are filtering out a large part of its spatial element. The band pass filter that we are applying to the brightness signal is also declining much of its time element. However, there will always be some level of this noise in the interest band.
- *User manners*: The force differences of the fingertip against the camera lens may show up in the signal. If the user has unbalanced hands, it is well that he uses a finger of the hand holding the phone.
- *Lighting variations*: Since the finger is lit at the back, any change in the light sources or in the scene replicating that light towards the camera may introduce noise in our pass band. For instance, moving the mobile in the air while recording the video, may lead artifacts.

The cutoff frequencies have been set to contain our band of interest: 50-220 bpm. An initial piece of 2 seconds are cut off the filtered signal. It is a guesstimate of the time it takes for the filter to completely eliminate the persistent signal offset. If this initial piece is not eliminated, we might get worst readings of the heart beat during the signal stabilization.

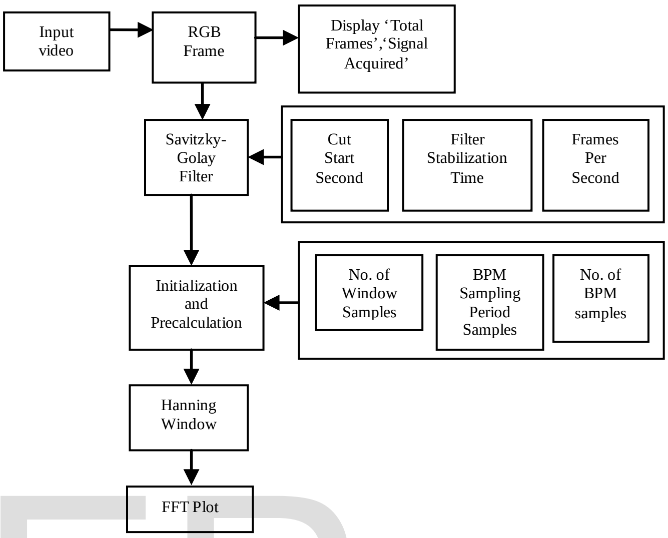


Figure 6. Architecture of FFT plot for the measurement of Heart Rate

## D. *Fast Fourier Transform*

The Discrete Fourier Transform (DFT) is used to transform the signal from the time domain to the frequency domain. The Fast Fourier Transform (FFT) was used to save processing time when calculating the DFT. While the computational difficulty of the DFT is O ($N^2$) for a set of $N$ points, the FFT gets the same results with O ($N \cdot \log_2 (N)$), which means a huge speed-up when $N$ is high.

There is an amazing command to calculate the FFT in Matlab. The FFT of a actual signal is a difficult signal which represents the magnitude and the phase of the resultant frequency. In the proposed system, phase is not needed.

In order to give a continuous evaluation of the heart rate, the FFT and the two steps (peak finding and smoothing) are repeated every 0.5 seconds. The window length directly affects frequency resolution and, thus, the accuracy of our estimation. However, increasing the window period decreases the time accuracy. If a peak is detected in the FFT, it is impossible when that tone started within the signal or how lengthy it lasted. The problem of a long window is that it will compel the user to wait for long duration to get a first reading after opening up the measurements.

Computing an approximate every 0.5 seconds does not progress the time accuracy of the output, but it increase the time resolution of the evaluation. It produces extra heart rate output samples per second that will be later smoothed to provide a more continuous and frequent reading. We are incrementing the time resolution of the evaluation but not its accuracy, which stay limited by the time resolution of the FFT.

The DFT works ideally with infinite time signals. A time limited signal of length N is the same to multiplying its infinite time matching part by a rectangular signal of length N and amplitude 1. According to frequency, this results in convolving the infinite time signal spectrum by the rectangular signal spectrum, produce leakage.

In order to reduce leakage, before computing the DFT, the input signal is multiplied by a role whose boundaries are zero. These forces the resultant boundary values to zero. The multiplying function is called "window". There are many window functions in the literature, each having their own virtues and disadvantages. The propoded system used the Hanning window because it offers good resolution and good leakage rejection.

In Matlab, the FFT magnitude with the Hanning window can be computed with the following code.

```
hanningWindow = hann(size(Window,2));
fftMagnitude = abs(fft (Window .* hanningWindow'));
```

## IV. RESULT AND DISCUSSION

After specifying all the parameters value in the architecture, we got an fft plot for the window duration of 10 sec as shown in figure 5.

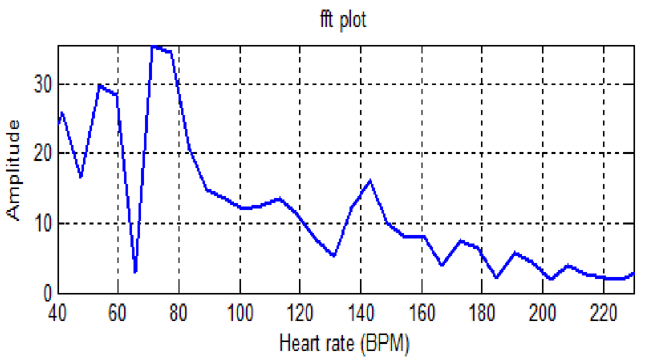


Figure 7. FFT plot of fingertip video

## V. CONCLUSION

Thus the fft plot of fingertip video has been achieved. This will be useful for measuring the heat rate. Only the red frames are considered to achieve the fft plot. The video to frame conversion converted number of frames depends on window length. The Brightness signal computation computes simple average of all the pixels in the red plane.

Savitzky Golay filtering reduces noise and Fast Fourier Transform (FFT) was used to save processing time when computing the DFT. Hanning window offers good resolution and good leakage rejection.

## V. FUTURE SCOPE

Once the FFT is computed for the current window, magnitude peaks in the interest band are spotted. The fft plot will be used for detecting peaks and smoothening the peaks for better accuracy of heart rate measurement.

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