Mini Project 1

SMART PHONE BASED PHOTOPLETHYSMOGRAPHY (PPG)

Smart Sensing for IoT

(CS6650)

M. Tech in Cyber-Physical Systems, IIT Madras, Chennai, India

Submitted By:

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Introduction

Photoplethysmography (PPG) is a simple and low-cost optical technique that can be used to detect blood volume changes in the microvascular bed of tissue. In this technique, light is shone onto a tissue containing blood vessels and then either the reflected or transmitted light is measured by a photosensitive element. By implementing this technique, oxygen level in blood can be estimated as well as heart beat can be measured.

Now a day, this technique has been incorporated into various devices. For example, pulse oximeter, wearable watches, and other health monitoring devices. In pulse oximeter, heart beat and SO2 is monitored and their readings are displayed on the screen.

Similarly, in this project photoplethysmography technique has been explored to detect the systolic and diastolic movement of heart by observing the blood flow and hence heartbeat. The blood flowing video has been recorded using smart phone camara and light projecting at the tip of finger. Using the data, heartbeat while taking rest, walking, and running have been studied by plotting various graphs. Randomly any 5 second chunk of the video is taken to study the effect of RGB channels at the level of frames and pixels. Finally maximum and minimum of 20 frames on RGB channel is plotted in order to estimate the threshold value for classify systolic and diastolic movement of heart. With the ROC graph between Pd (Probability of detection) and Pfa(Probability of false alarm), the optimal threshold on red channel has been found out 236.

Specification of Videos

There are different videos have been recording to illustrate the heartbeat while taking rest, walking and running. The resolution of video is 480x850 at 60 fps for 10 seconds.

Heartbeats Observation

Heartbeat is a periodic movement which is generated by heart to circulate the blood throughout the body in order to transmigrate the essential elements to each cell for their nourishment.

To study the heartbeat rate, three different 10 second videos have been recorded. The videos data have been studied plotting different graphs. Heartbeat can be approximated by counting the number of peaks. Here peaks represent systolic movement while diastolic movement is represented by bottom of the graph. So, from the fig.1, it can be depicted that the heart rate while taking rest is approximately 13 times which is nearly 78 times per minute. Similarly, heartbeat rate while walking is approximately 15 times (i.e nearly 90 times per minute) and approximately 18 times (i.e nearly 108 times per minute).

It shows while running our heartbeat surges high to meet the demand of high consumption of energy by cells. Hence, beat is faster in comparison of beat at rest or while walking. From the graph, we can also observe another important phenomenon that systolic movement duration is more whereas diastolic is lasting for less moment in each cycle. One heartbeat cycle is composed of one systolic and one diastolic movement.

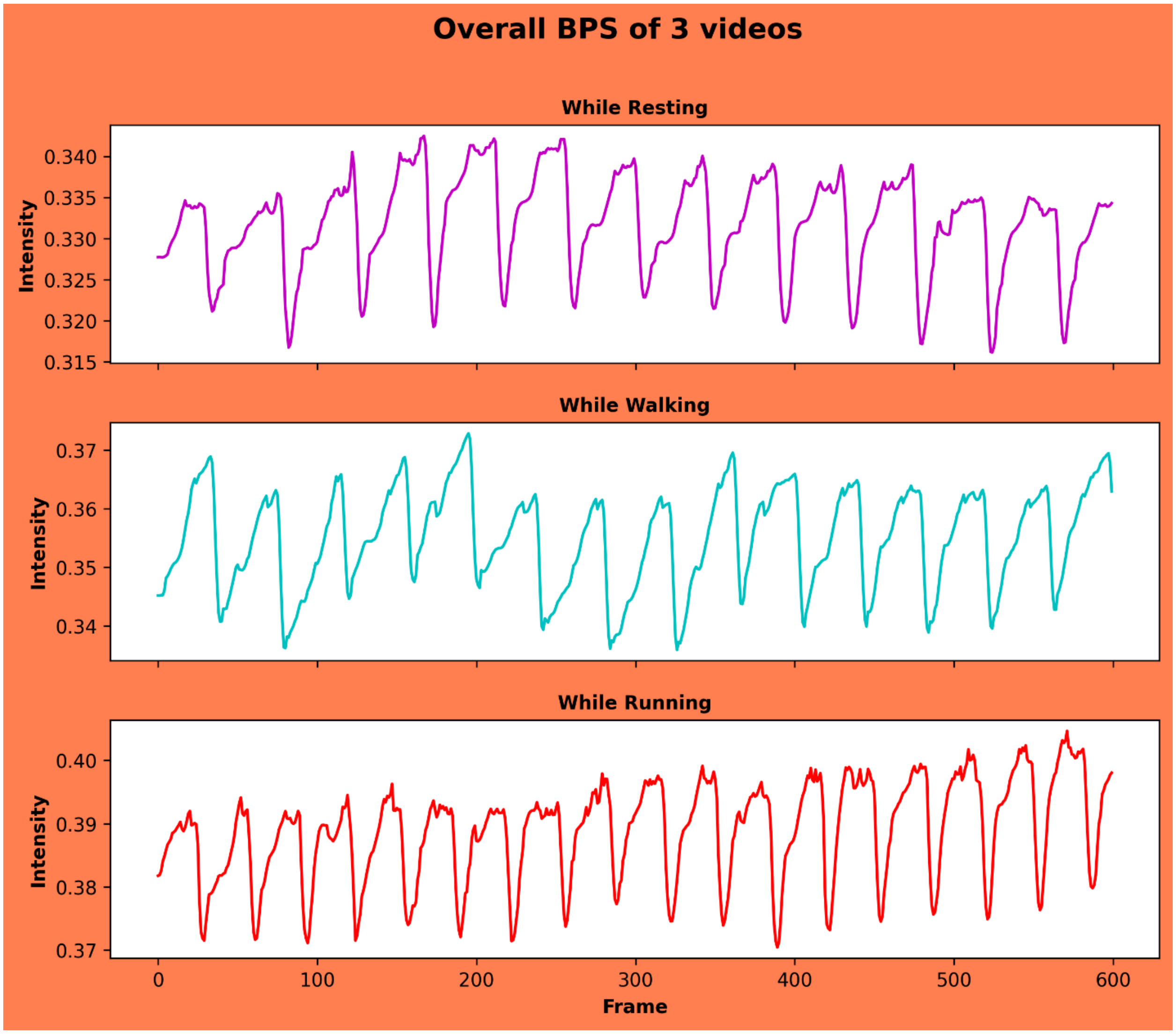

fig. 1. The pattern of heartbeat of different situations in 10 sec recorded videos.

Sensing Metric

By using cv2 library, videos are read and stored in three different arrays called vF1, vF2 and vF3. Further, each video is dissected into RGB channels and the respective color values of each pixel of each frame is stored in another array in normalized form, array is called norm_bluevF1 (of video1) and similarly for others videos. Later mean value of each frame corresponding to blue channel is calculated and store in variable called norm_bluevF1_mean and similarly for other channels for each video. The mean value of each frame of particular channel helps to get the idea of impact of channel on detection of maximum and minimum in graph.

Temporal Variation of Intensity Value

Here randomly 5 second chunk video is taken and plotted a graph for each video. Each video contains 60x10 frames and in each in frame there are 480x 850 pixels. Since we have already calculated the average value for each frame, hence all pixels of a frame become one value as average. Here, we can plot of 5 second chunk video in fig.2. For each frame, their average RGB channels values have been added and divided by 3 to make an average and then it is plotted.

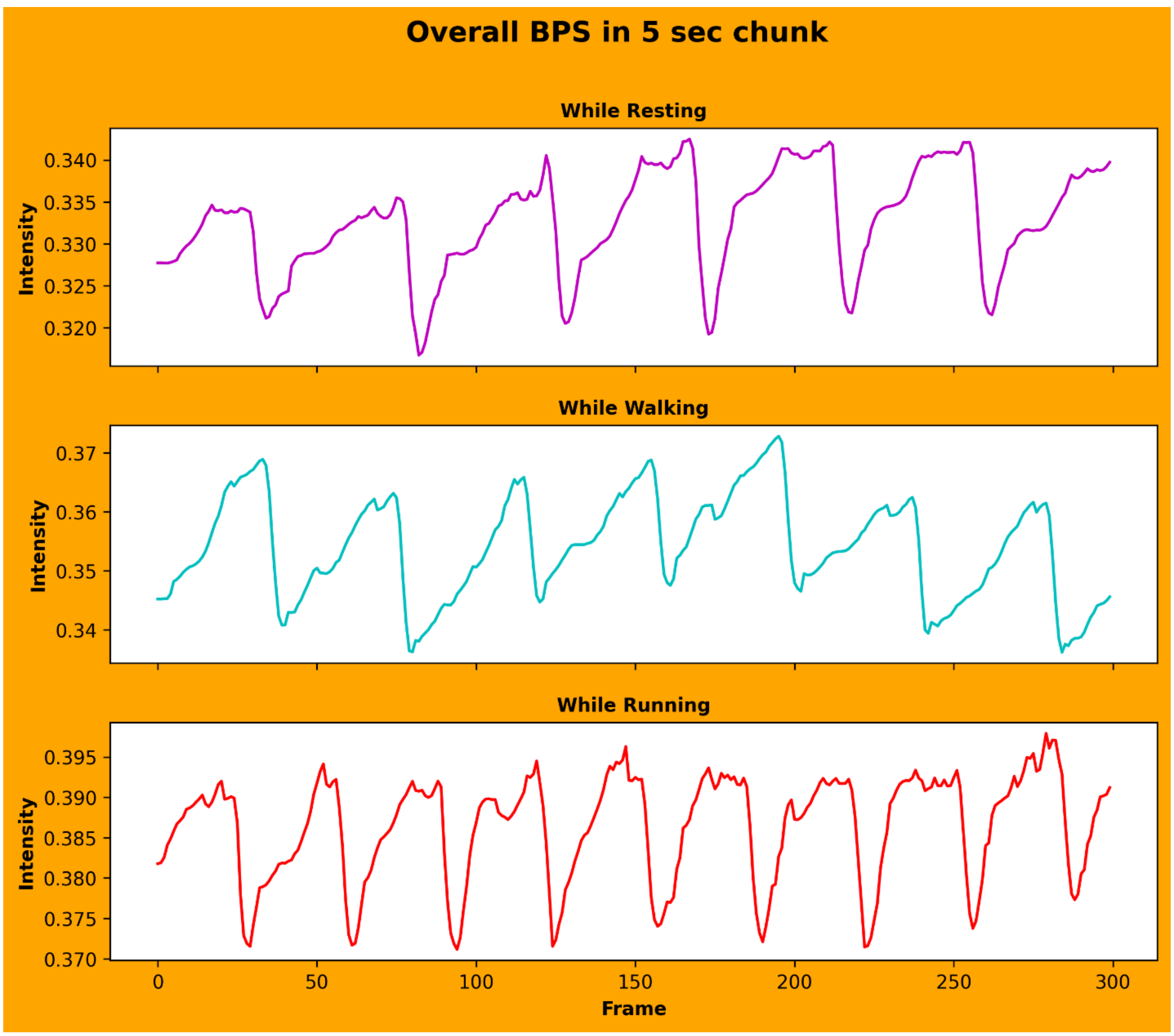

Fig. Heartbeat pattern in 5 sec chunks of video

Likelihood Distributions

To study the maximum and minimum (i.e systolic and diastolic movement of heart), 20 frames for each case have chosen for three videos. We have created one variable to store the selected 20 frames including maximum and another variable to store 20 frames including minimum. It is done for each channel and for each video. By plotting the histogram of each case help to study the distribution of different channels in frames and their impact to detect heartbeat.

For **video 1**, the channel distribution during heartbeat has been depicted in fig.3. It clearly shows

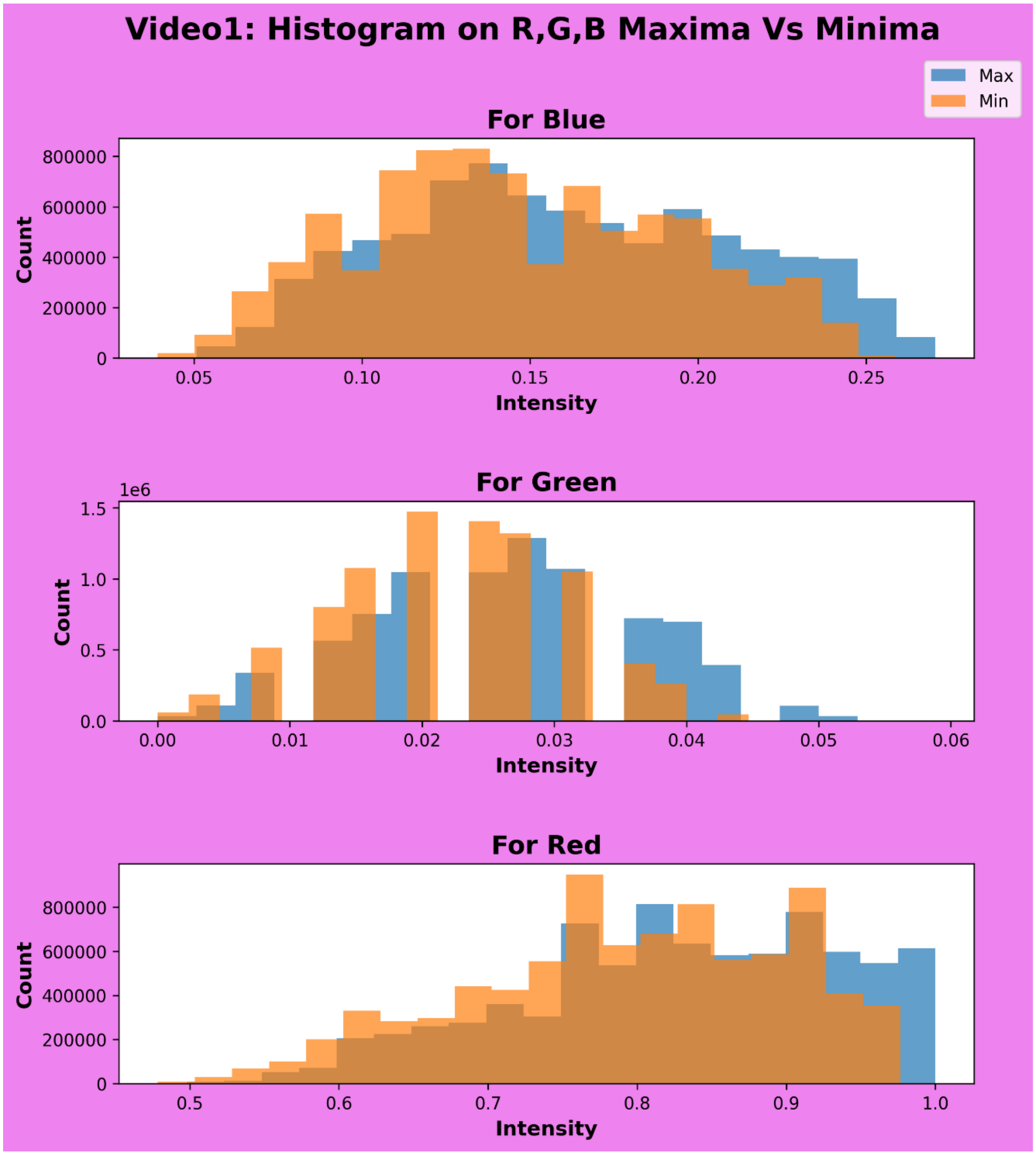

Fig.3 RGB channel study of heartbeat in 20 frames (video 1)

That how count of different RGB channel of pixels is varying during the maximum and minimum state. It shows all channels are getting overlapped because maximum and minimum both contains channel of same intensity. However, in maximum, it also contains some pixels having highest intensity which makes the maximum pixel distinct from minimum though it is small in number.

Similarly, we have another plot for video2 as shown in fig.4. It shows that overlapping is nothing

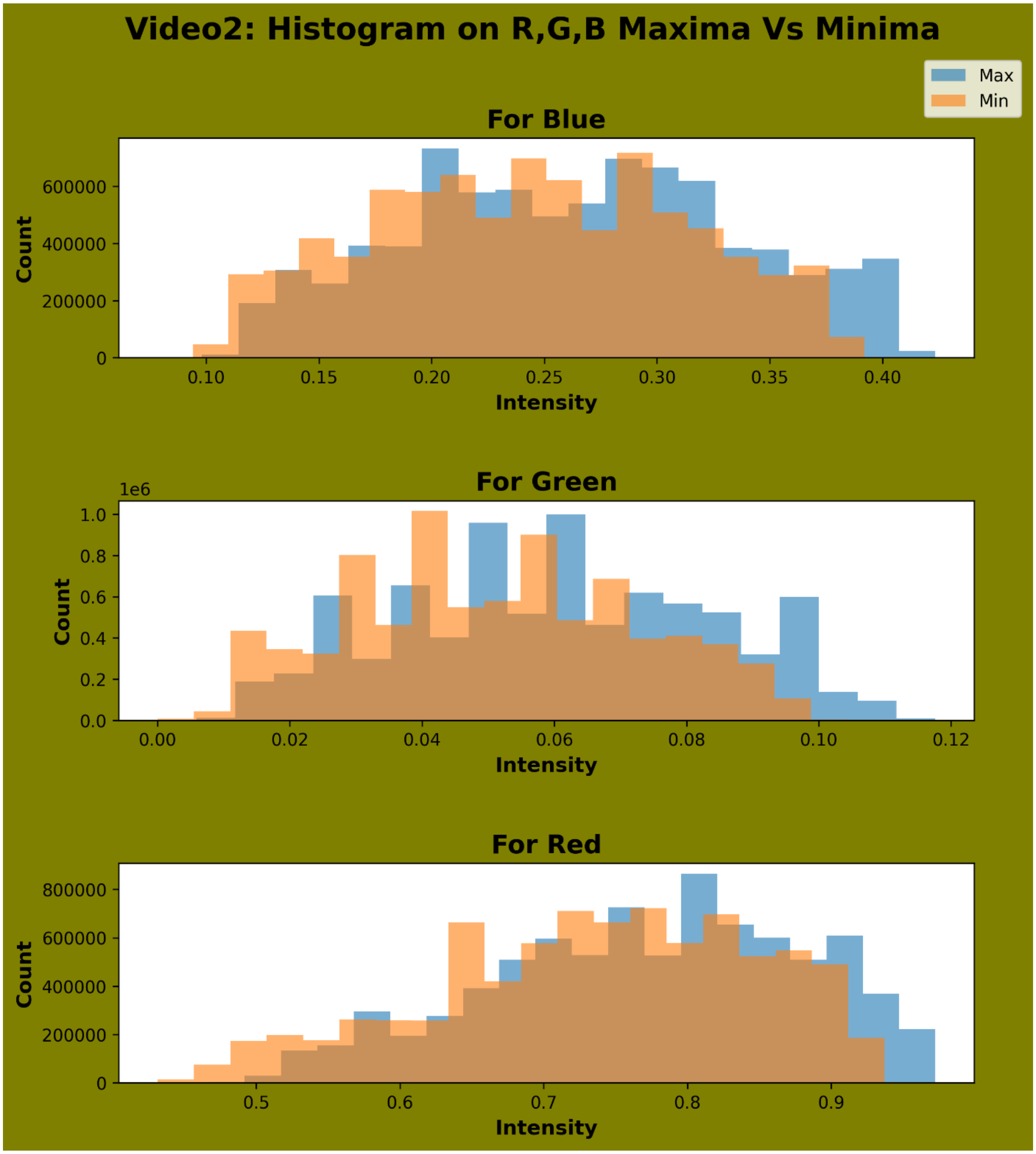

Fig.4 RGB channel study of heartbeat in 20 frames (video 2)

But a kind of noise which causes problem in identifying maximum and minimum state as there will be very less gap between them if there is overlapping. However, in our plot we are getting very less gap of intensity between the two states.

Similarly, we have histogram plot of maximum and minimum cases over RGB channel as shown in the figure below fig. 5. Overall it is observed that there is very small difference between maximum and minimum cases on each channel. In video 1 and video 2, there is a gap on each

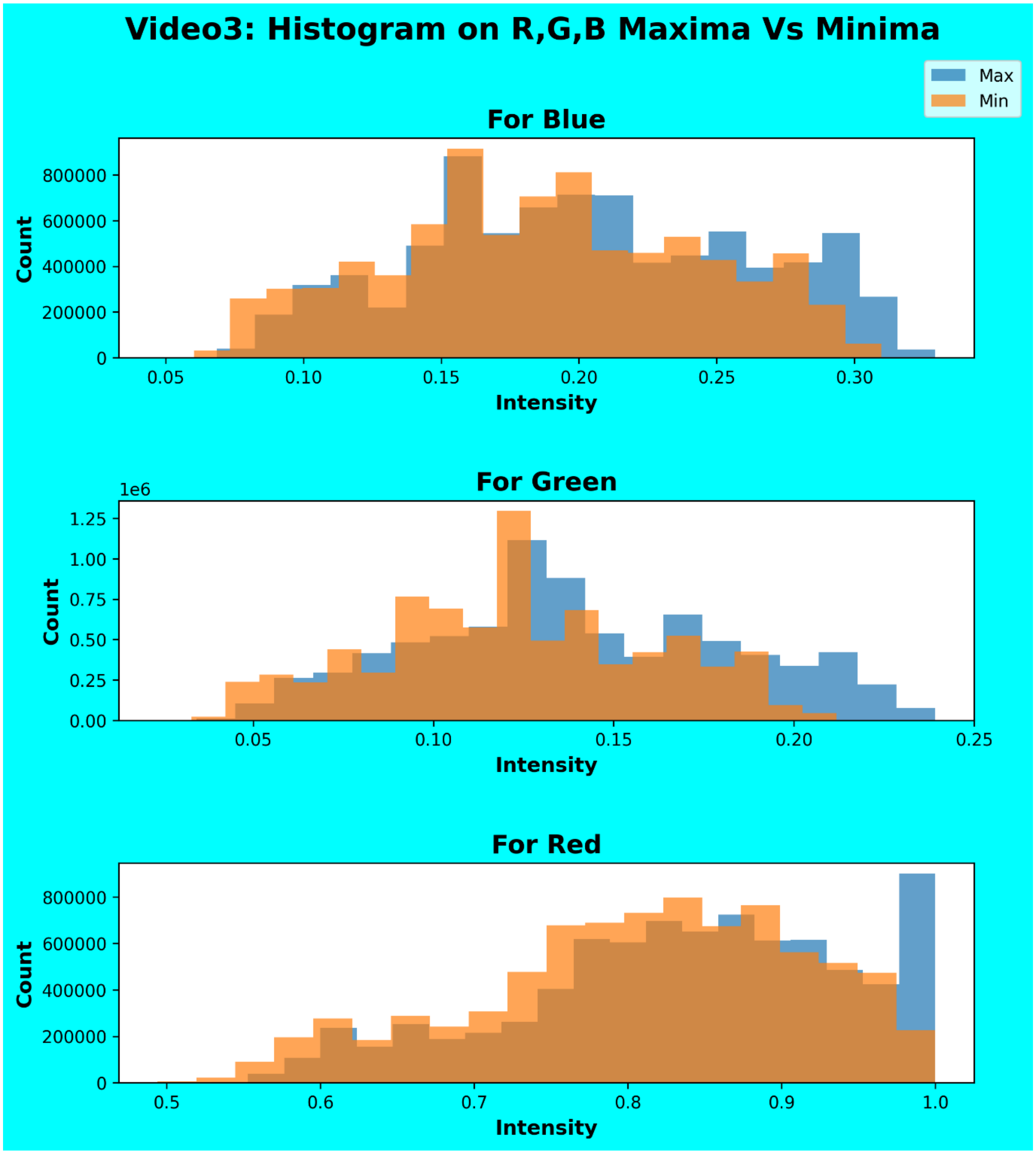

Fig.5 RGB channel study of heartbeat in 20 frames (video 3)

channel whereas there is a gap on blue and green channel in video 3. In video 3, red channel is seen completely overlapped.

Threshold Based Detection and ROC Curve

Now, we have focused on “Red” channel to dive deep to investigate maximum and minimum cases in detail. To classify any pixel to be either belongs to maximum or minimum, there must be a threshold value of intensity. If pixel intensity is greater than the threshold value then it belongs to maximum otherwise belongs to minimum. Since our graphs are very badly overlapped, hence threshold value is going to very close to the end value where cases are very feebly separated. From each video, randomly 500 pixels in each frame and total 20 frames for each cases have been chosen to perform an experiment to find out threshold. Threshold hold value is varied from 0 to 255 and probability of detection and probability of false alarm is calculated and plotted in graph. Probability of detection is calculated by taking ratio of the count of pixels of maximum which intensity value is greater than the instant threshold and total counts (20x500). Similarly, probability of false alarm is calculated by taking ratio of the count of pixels of minimum which intensity value is greater than instant threshold.

For video 1, we have got ROC curve after plotting Pd vs Pfa as shown in figure 6. As we see in the figure, first Pd value increases suddenly without causing any change on Pfa value. It shows

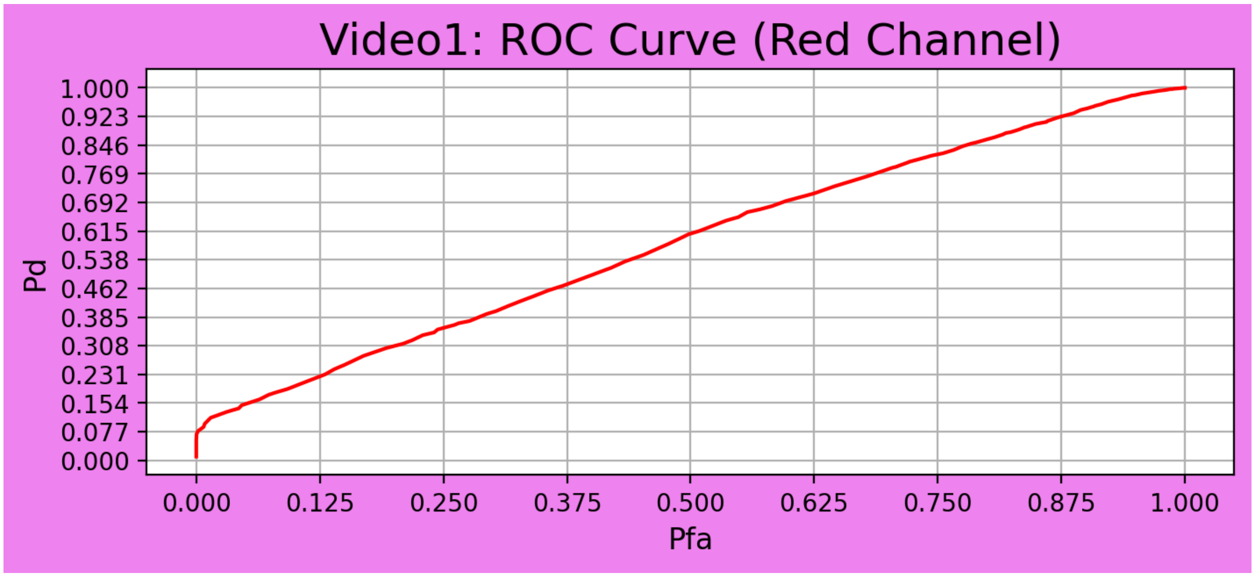

Fig.6 ROC curve illustrating threshold for red channel (Video 1)

during that interval, only there is change in maxima not in minima. Hence the corresponding intensity value of red channel can be threshold value.

Similarly, we have another ROC curve for video 2 on red channel as shown in figure 7. Here also we have got same value as in video 1. The graph is making curve at 0.077 on Pd axis along 0 on

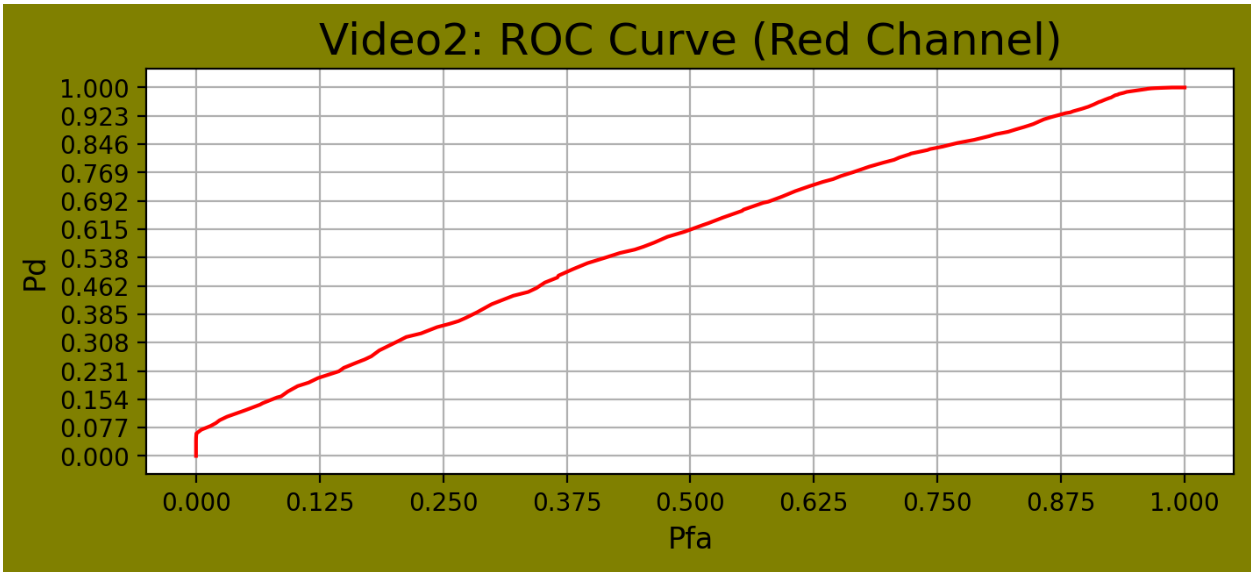

Fig.7 ROC curve illustrating threshold for red channel (Video 2)

Pfa axis. Similarly, we have another ROC curve for video 3 and has same value as shown in fig.8.

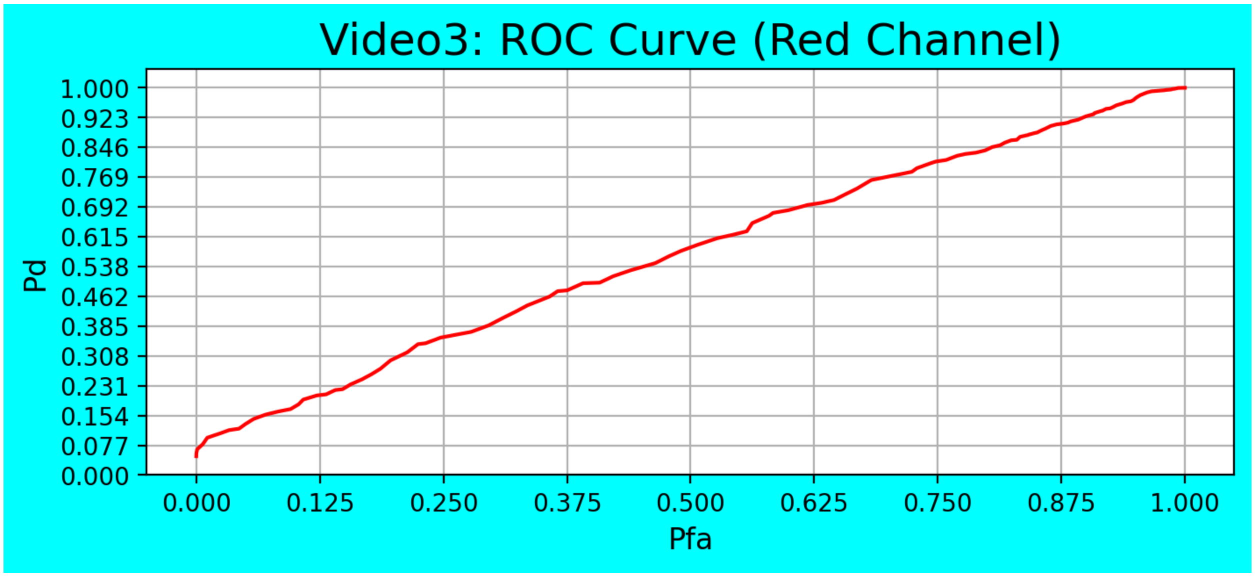

Fig.7 ROC curve illustrating threshold for red channel (Video 2)

On the observing the ROC curve of all three video for red channel, it is found out that threshold value for red channel across video remains same. Our threshold value is located at the curve 0.077 unit along Pd axis while 0 unit along Pfa axis. Hence, threshold value is calculated as:

Threshold value = (1-0.077)*255 = 236

It shows the pixel having red intensity greater than 236 belongs to maximum otherwise to minimum.

Spatially Correlation

The optimal threshold value is that value which maximizes the Pd (probability of detection) and minimizes Pfa (probability of false alarm). As we see in above ROC curves, it is clearly depicted as we go above the value 0.077, Pd increases proportionally to Pfa. Hence, there is no significance in moving the point. Thus, the obtained threshold value is our optimal value for red channel.

While illustrating the statistical parameter based on the obtained threshold over the 20000 detections, the following conclusions have been obtained. It shows that at our threshold value, density of true positive is small and false positive is extremely low. It illustrates that our model is very much sensitive toward detecting positive. There is very less probability of mistakenly detecting positive. This kind of model is applicable in some part of medical field to confirm acute disease. If it detects positive then it is almost 100% confirm that he/she is having that disease.

```
For Video1:
                 True          False
 Positive        0.10385       0.0539
 Negative        0.4461        0.39615

For Video2:
                 True          False
 Positive        0.03565       0.0027
 Negative        0.4973        0.46435

For Video3:
                 True          False
 Positive        0.11085       0.074
 Negative        0.426         0.38915
```

Fig.9 Statistical value of threshold over 20000 detection

Conclusion

Photoplethysmography is hands on technique and makes easy to examine the different parameters of blood such as pulse rate, oxygen level and other health related information. In this project, video of tip of finger is recorded using mobile camera and explored to find out the pixel level threshold value for “R” channel and it is found to be 236 and examined with the help of receiver operating characteristics (ROC) curve.