Estimate Heart Rate Report

GitHub Link:
https://github.com/EshitaKhanna/SRIP-2023-Smart-Mask-Submission/tree/main/Task%202%20-%20Estimate%20Heart%20Rate

Introduction
Photoplethysmography (PPG) technique is a non-invasive optical measurement technique used to measure the changes in blood volume in tissues. When a light source illuminates tissue, some of the light is absorbed by it while some are reflected back. The amount of light reflected depends on the blood volume in the tissue, which varies with the heartbeat.
A PPG device consists of a light source and a photodetector. The reflected light is detected by the photodetector and converted into an electrical signal, filtered and processed to obtain a waveform that represents the fluctuations in blood volume. This waveform is used to measure parameters like heart rate and blood pressure.

Overview
The heart rate monitoring system measures the user's heart rate based on smartphone Photoplethysmography. PPG signals can be obtained from smartphone camera recording. The fingertip of the user is placed on the camera of the smartphone, and a video is recorded with the flash on. The flash acts as a source of light while the camera is a photodetector. Processing algorithms are applied to these recordings to extract the heart rate of the user.

Algorithm
1. The video recorded by the user is split into frames. Each video frame consists of Red Green and Blue channels. These channels are extracted and the mean of each RGB channel is calculated. For each channel, time-series waveforms are plotted.
2. To extract heart rate from the signal, we use green and red lights. Light with longer wavelengths penetrates more deeply into the tissue. Red light has more penetration power than green light. However, red light is susceptible to motion artifacts which would require additional filtering. Thus, we use green light as it has a shorter wavelength and absorbs well into the skin.
3. Filtering: The color of the skin varies due to numerous factors such as voluntary or involuntary muscle movement, changes in the light in a room, and respiration. As a result, these frequencies are also picked up and need to be filtered. To filter these frequencies, a bandpass filter is applied that removes the frequencies that are greater than the maximum and lesser than the minimum heart rate of a human.
4. Remove the video's initial part (3 seconds) for camera stabilization.
5. Detect heart rate by 2 algorithms:
    a. Peak Detection
    b. FFT-based peak detection
        i. Find the frequency with the most prominent magnitude in the video corresponds to heart rate.
6. Calculate heart rate by multiplying the value of peak by 60 (to get an output in bpm)

Data Collection
Data has been collected from 5 users in two finger orientations (horizontal and vertical). I have used the Instant Heart Rate app for ground truth.

I have used a Samsung M31 phone (Users 1,2,3) and Pixel 3XL (Users 4, 5) for capturing the video at 30 frames per second.

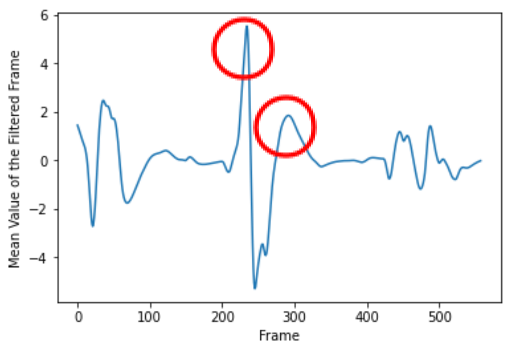
Link for data:
https://github.com/EshitaKhanna/SRIP-2023-Smart-Mask-Submission/tree/main/Task%202%20-%20Estimate%20Heart%20Rate/Data

Link for python code:
https://github.com/EshitaKhanna/SRIP-2023-Smart-Mask-Submission/blob/main/Task%202%20-%20Estimate%20Heart%20Rate/Heart_Rate_Monitor.ipynb

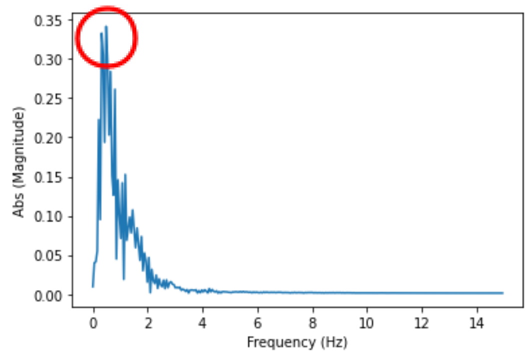
Evaluation

User ID	Gender	Age	Finger orientation	Ground truth (bpm)	Heart rate: Peak Detection (bpm)	Heart rate: FFT (bpm)	Mean Absolute Error (Peak Detection)	Mean Absolute Error (FFT)
1	Female	48	Vertical	84	77.55	81.72	7.67	2.71
			Horizontal	82	80.26	80.35	2.12	2.01
2	Female	18	Vertical	102	101.7	12.66	0.29	87.58
			Horizontal	107	73.64	104.09	31.17	2.71
3	Male	53	Vertical	70	71.41	71.49	2.01	2.12
			Horizontal	71	70.91	70.99	0.12	0.01
4	Female	25	Vertical	65	60.64	19.32	6.70	70.27
			Horizontal	60	51.52	29.03	14.13	51.61
5	Male	25	Vertical	70	60.90	30.50	13	56.42
			Horizontal	84	76.00	86.53	9.52	3.01

Analysis: The heart estimates from both the algorithms, for most of the cases are very close to the ground truth. This demonstrates the system's efficacy in heart rate estimation with varied user age groups, smartphones, and orientations.
For some of the uses (U4 Horizontal Orientation) the data was a bit different. As seen in the plot below we can see two high-magnitude low-frequency peaks (marked in red). These peaks give rise to a low-frequency high magnitude peak in the frequency spectrum, yielding largely heart rate estimates. Peak detection still somehow manages to find more accurate estimates. And this mostly happens in the vertical orientation. It can be that users were not comfortable or did not follow instructions properly.



Mean Value of the Filtered Frame
Frame



Abs (Magnitude)
Frequency (Hz)