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Project Report: *TrackBeat*- Android application for detecting Heart-rate from Video of Human Head

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We present 'TrackBeat', an Android application to extract human pulse information just from a video of the Human head. It does this by measuring subtle head motion caused by the Newtonian reaction to the influx of blood at each beat. The implemented method tracks features and performs Principal Component Analysis (PCA) to decompose trajectories into a set of component motions. It then chooses the component that best corresponds to heartbeats based on its temporal frequency spectrum. Finally, we analyze the motion projected to this component and identify peaks of the trajectories, which corresponds to heartbeats. All this is optimized to work on a constrained computing platform of an Android Phone.

1 Introduction and Motivation

Heart rate is a vital sign for Medical Diagnosis. There is a growing interest in extracting the heart rate without contact, i.e., a non-invasive approach, particularly for populations such as premature neonates and elderly whose skin is fragile and damageable by traditional sensors. Furthermore, continuous or at least frequent monitoring outside of clinical environments can provide doctors with not just timely samples, but also long-term trends and statistical analysis.

With this in mind, we implemented a system to extract the cardiac activity from short videos of the human head due to subtle head motions which accompany the cardiac cycle. This follows the work of Balakrishnan et al., CVPR 2013 [1]. But this work uses a stationary camera fixed on a tripod stand and all computations are performed on a desktop computer. We believe that a system like this is more appropriate on a mobile computing platform such as an Android Phone, which would easily make such technology available to the masses.

2 Related Work

There has been significant work done in extraction of heart rate using non-invasive approaches. Poh et al. [2] detected pulse rate from the subtle changes in face color in a blood circulatory cycle. This method requires good lighting conditions as well as exposure of facial skin which is not a necessicity for our approach [3]. The Phillips vital camera app [4] incorporates this approach and even allows the measurement of heart rate from two different subjects in the same camera frame.

Photoplethysmography (PPG) is used to estimate the skin blood flow using infrared or visible light [5]. Essentially it involves illuminating a region rich in capillaries (eg. Fingers) with a high frequency light pulse and measuring the time it takes for the blood stream to reflect the pulses. There are several Android apps available that use this technique to determine the heart rate with good accuracy[7]. These apps require the user to place a finger on the camera, and only works well with a flash. We tested quite extensively with Azumio Inc's Instant Heart Rate app and observed inconsistencies in the readouts.

Due to recent technological improvements in the field of piezoelectric sensors, Ballistocardiography (BCG), an almost forgotten physiological measurement, is now being object of a renewed scientific interest. Recently, He et al.[6] proposed exploiting head motion measured by accelerometers for heart rate monitoring as a proxy for traditional BCG.

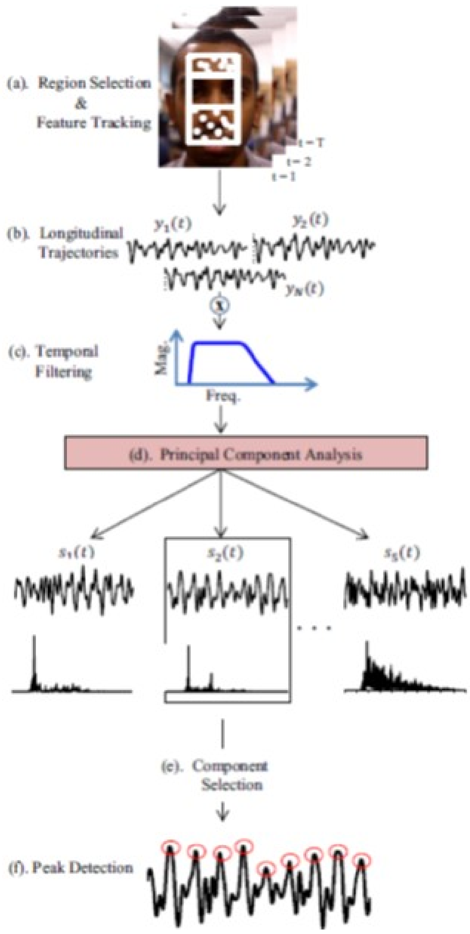

Figure 2.1: Overview of the Pulse Estimation Algorithm *Source: Balakrishnan et al., CVPR2013 [1]*

3 METHODOLOGY

Our method follows the implementation of Balakrishnan et al. [1]. We start off by detecting a face in the camera view and locating tracking points on the face, which are then tracked throughout the video length. These trajectories are then subjected to temporal filtering in order to limit the frequencies considered to a reasonable range. After this we perform Principal Component Analysis on the data in order to break up the trajectories into component trajectories and select the top few of them. These selected few trajectories are then analyzed in frequency domain and the most periodic one of them is selected for further analysis. Peak detection is then performed on the final selected trajectory, which gives us our estimate of the heart rate of the subject.

3.1 PHYSIOLOGY

The head movement caused by cardiac activity is quite small in general, with the upper bound amplitude being 5mm in the vertical direciton. From a biomechanical standpoint, the head-neck system and the trunk can be considered as a sequence of stacked inverted pendulums. This structure allows the head unconstrained movement in most axes.

Apart from cardiac activity there are 2 other major sources of involutary head movement. One is the movement of the chest and head due to respiration. This is dealt with by temporally filtering out the low frequncy components in the trajectories of the tracking points. The other is the pendular oscillatory motion that keeps the head in dynamic equilibrium. It has been stated in [1] that this motion has most of its components in the horizontal direction. Therefore we track the movement of feature points only in the vertical direction.

3.2 FACE DETECTION AND TRACKING

Face Detection is accomplished using OpenCV's Cascade Classifier that is trained using Local Binary Patterns. In our implementation we run the face detection module and wait for five continuous detections before moving on to Tracking module. This ensures that our application is robust to false positive detections.

Once we have a detected face, we locate Feature points using OpenCV's *GoodFeaturesToTrack* method. In order to avoid getting outliers we focus on feature points located either on the forehead or the nose and mouth of the subject. This makes the method robust to eye movments and blinking.

Our DataCollection module stores *y coordinates* for tracking points across multiple frames and passes this Data to the DataAnalysis activity.

3.3 TEMPORAL FILTERING

The first task accomplished by our DataAnalysis module is Bandpass filtering the trajectory data so that we don't have to worry about periodic motion arising from resperiation amongst other physiological operations. For this purpose we create a Butterworth bandpass filter with a frequency range of [0.75,5] Hz and process our timeseries data with it. We try to keep higher frequencies because it is claimed by [1] that this helps in the PCA step which follows this.

3.4 PRINCIPAL COMPONENT ANALYSIS

Once we have the filtered timeseries with us, our DataAnalysis module computes the principal components of all the samples and projects the samples onto the five most prominent eigenvectors from the eigenbasis of the data. We now must choose to calculate heart

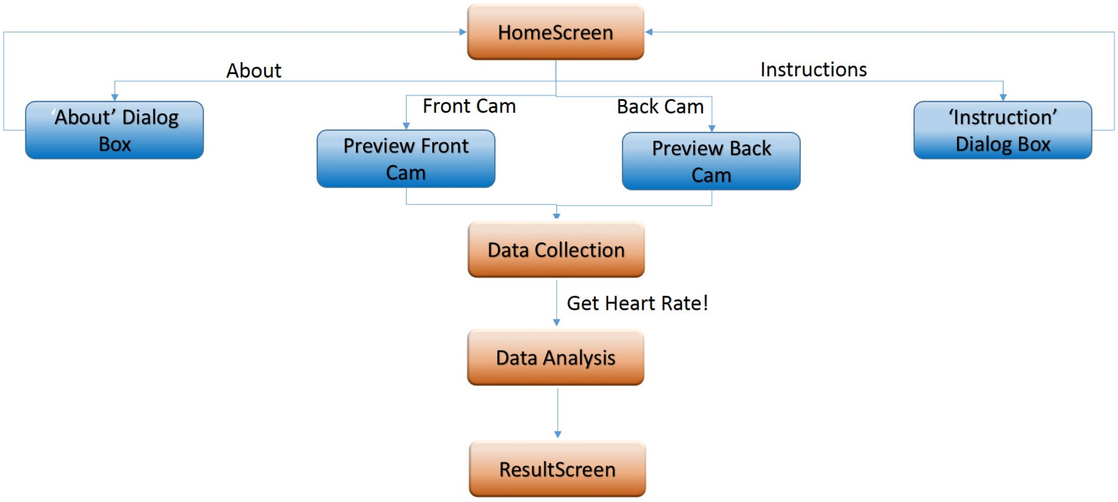

Figure 3.1: Flowchart depicting the App modules

rate from one of these five trajectories. This is accomplished by the next submodule.

3.5 Signal Selection

In order to select one trajectory, we analyze the frequency spectrum of each of the trajectories and select one which has gretaer part of its spectrum belonging to a particular frequency. In other words, we select that trajectory which is *most periodic*. This trajectory is then analyzed by peak detection algorithm, and heartrate is computed using the *average frame distance between consecutive peaks*.

4 App Details

The application is driven by 3 modules namely the Homescreen, DataCollection and the DataAnalysis activities. Figures 4.1, 4.2 and 4 depict the Screen views for each of these three activites respectively. Figure 3.1 depicts the transfer of control(navigation) between these activities.

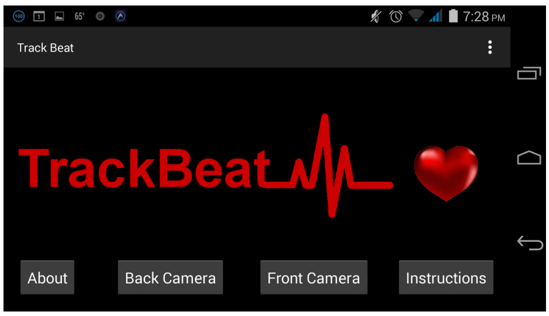

Figure 4.1: HomeScreen UI

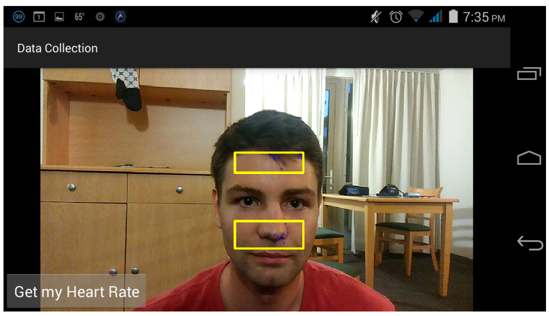

Figure 4.2: DataCollection UI

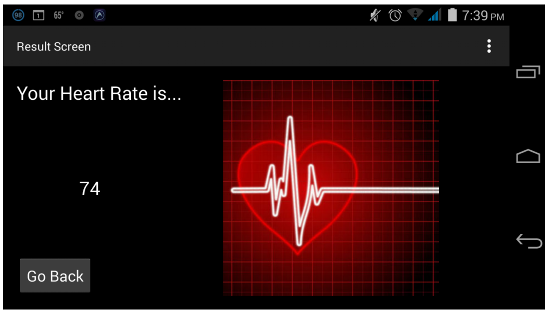

Figure 4.3: FinalScreen showing results of heartrate in BPM

4.1 Challenges

There are many challenges associated with getting our application to work properly, namely:

- Getting good features to track is a problem, because it is difficult for the subject to stay still even for short periods of time
- Handling dynamic data in Java has been a challenge for the authors. Therefore, certain things that could have improved the performance of our application have not been implemented. One of these is outlier rejection within tracking points.
- The frame rate achieved with our BLU Studio X device was around 8 fps on an average. On the other hand the electrocardiogram takes around 120 samples per second. This accounts for a drop in accuracy on our part.

4.2 Instructions for use

Users must note that the Head position must be fairly *stationary* after the face is detected. Needless to say, so must the camera. A stand for the phone is ideal. Also, face detection fidelity varies with lighting conditions, so users must make sure that any light source must be in front of them.

1. On the Homepage, select the Front Camera if you wish to obtain your own pulse rate or the Back Camera if you wish to obtain a friend's pulse rate.
2. A Camera preview opens. After a while, your face should be detected, which is indicated by two rectangles over the face. Tilt your head left-right to get face detect results if they are not immediately displayed.
3. After around 20 seconds, press 'Get my heart Rate!' to get a readout of your heart rate on a new screen!

5 Experiments

We tested the App on several devices, and perfomed extensive experiments with the App at three different times on 4 different subjects. The app was run on an inexpensive low-end Blu Studio X Android 4.4.2 smartphone with a 1.3 GHz Processor and 1GB RAM, with a 8.0 MP 30fps back camera and a 2.0 MP 30fps front camera. We connected the subjects to a wearable ECG monitor for ground truth comparison. Also, we compared the results of TrackBeat with the Instant Heart Rate monitor by Azumio Inc, available for free from the Google Play store. The results for the comparison experiments are presented in Table 5.1.

6 Conclusion

We successfully implemented a system to extract the Cardiovascular activity of humans from a video of the head. The system was packaged into an Application for the Android Platform with a simplistic UI. The App shows

Table 5.1: Results(in BPM)

		ECG	PPG	TrackBeat
Samson	**T1**	47	49	54
	T2	107	95	65
	T3	55	56	58
Rohan	**T1**	63	61	71
	T2	118	83	86
	T3	86	82	91
Praveen	**T1**	73	69	76
	T2	96	90	90
	T3	82	97	88
Christol	**T1**	96	96	83

promising results in the comparison experiments we performed against ECG Ground truth and a PPG App, with 4 subjects at 3 different times. We find that the system is not robust to camera motion, and does not give accurate results when the subject is breathing heavily (after excercise etc.). This can be attributed to the interference by components of head motions due to respiration. Also, results are dependent on lighting conditions. In the future an interesting field to investigate further would be video stabilization for mobile platforms.This would make the system more robust to camera motions.

References

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