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# Extracting vital signs with smartphone camera

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PROJECT

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# Abstract

Due to the large number of smartphones there today, it makes almost everyone has in his hand an unimaginable amount of information, assistance, entertainment...

In this project we talk about an important issue such as e-health.. We boarded the possibility to inform a patient of a vital sign as is the heart rate. We will use an app for Android operating system, the operating system most currently used.In this way we can reach a large audience without any charge, just by downloading a free app. This app has been developed thanks to the electronics department and supervisors Hamed and Ilangko.

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# Contents

# Chapter 1

# Introduction

The objective of this project is to determine a vital sign of a person through the camera of a mobile device and an application for that mobile. The technique used is called Photo-plethysmography (PPG). Plethysmography is the technique for detecting cardio vascular pulse wave traveling through the human body.

The application developed is called **HR detector**. This application is written primarily in Java and some C ++. The reason is written in Java is mainly because it is based on the Android mobile operating system. Mainly it used the open source OpenCV library. This library is also available for different programming languages such as C ++ and Python.

Users may itself get your own heartbeat with its own device. The device must have front camera, so the user is able to time as his face has been detected and can finally see his heartbeat on the device screen. To use the **HR detector** application, previously we have to download the **OpenCV Manager** application. With **OpenCV Manager** in our device we will have the latest OpenCV libraries for our hardware.

Of course the PPG (photoplethysmography) technique is not 100% reliable. In our case, certain factors come into play by the device such as the quality of the front and camera hardware device. There are also other factors external to the device such as the light in the place where they are performing data collection or characteristics of the person using the app.

# Chapter 2

# Theory

The content of this chapter describes what photoplethismography (PPG) is and what can be expected from the implementation presented in this report.

## 2.1 Background on photoplethysmography

From the Greek word plethysmos to increase, plethysmography means "[...] finding variations in the size of a part owing to variations in the amount of blood passing through or contained in the part." Plethysmography refers to the technique for detecting cardio vascular pulse wave traveling through the human body measuring pulsatile tissue volume directly. Arterial pulsations are the most significant reason for volume changes. Capillaries are largely non-compliant and will register only minor pulsations. The plethysmogram is used as an indirect measure for arterial blood pressure (ABP). [1]

With a digital camera in movie mode using ambient light Photo-plethysmography signals can be measured remotely or internally. PPG is based on the principle that blood absorbs more light than surrounding tissue so variations in blood volume affect transmission or reflectance correspondingly. In red blood cells, one of the major components is oxygen carrying protein, hemoglobin, pigmented with red color. This characteristic makes the light properties of blood different from surrounding tissues. The hemoglobin absorption spectra give us a key factor in our application.

As we can see in Figure 2.1, the absorption is highest for the green part of the spectrum and

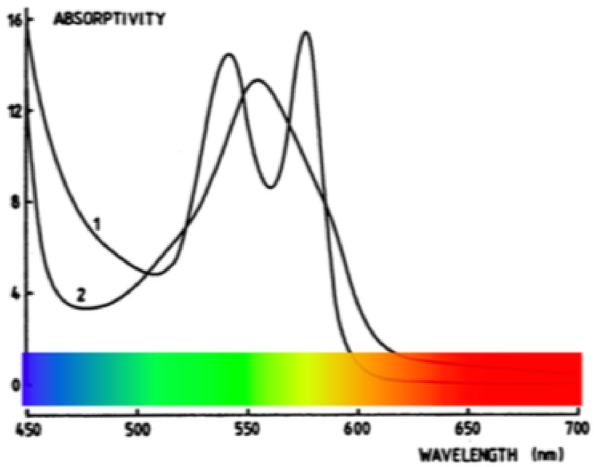


Figure 2.1: Absorption spectra.

it is lowest in the blue part. PPG signals can be divided in two parts: DC component and AC component.

- DC component: A constant voltage offset determined by the nature of the material the light passes through.

-AC component: Component synchronous to the heart rate. The AC component of PPG pulse shapes are indicative of vessel compliance and cardiac performance.

In the AC component of PPG signal we can see the changes by fluctuations due to blood flow with the highest amplitude values in the areas with highest absorption. Our analysis is based on the statistical signal processing theory and the knowledge about the hemoglobin absorption spectra.

## 2.2 Implementation of the algorithm

The Implemented algorithm is described in the figure 2.2. The first step in order to get the heart rate is to select in the captured frame the Region Of Interest (ROI). In our case, we are looking for faces, specifically, the forehead, in which we can better detect the skin. The face detection will be done thanks to OpenCV library. Using RGB colour map, the green colour is detected. This channel is chosen because the oxygen filed hemoglobin absorbs more of the green light, as we can see in Figure 2.1.

After detecting the green colour in the ROI, all the green values in the ROI in one frame

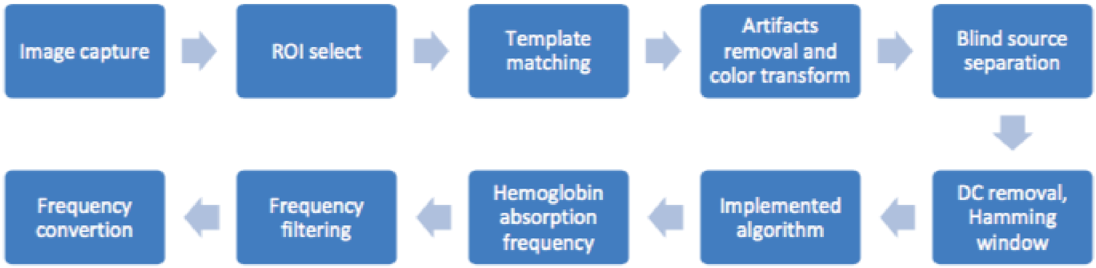


Figure 2.2: Flowchart.

is summed to one sample. This is repeated for all the frames, before the average value of all these samples are used to remove the DC. Filtering the redundant frequency components, the optimum one is chosen as the frequency with the highest power spectral density. The heart rate is then obtained by converting from frequency to bpm.

There are some algorithms that have been tested and proven as: FFT, MUSIC, ESPRIT or AR (Autoregressive mode). Chosen for their easier implementation in the Java language has been FFT. The fast Fourier transform is a mathematical method for transforming a function of time into a function of frequency. Sometimes it is described as transforming from the time domain to the frequency domain. It is very useful for analysis of time-dependent phenomena.[2]

The most used FFT algorithm is the Cooley-Tukey algorithm, which consists on dividing the transform into many smaller DFT. This algorithm can be combined with as Prime-factor FFT or Bruun's FFT algorithm. In the Figure 2.3 we can see the result of having applied the FFT.

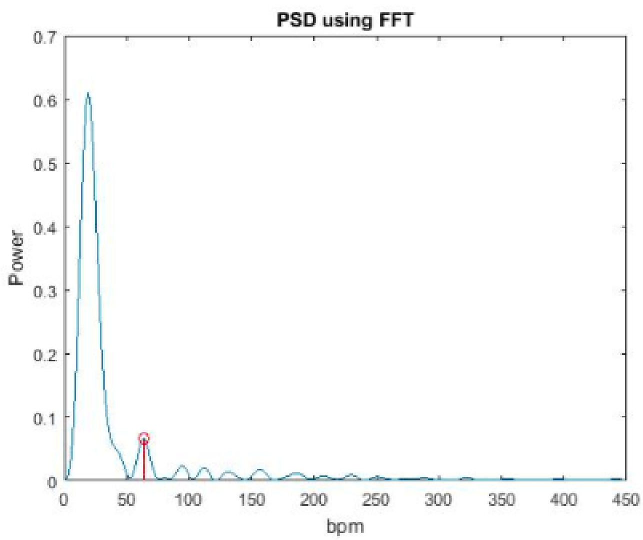


Figure 2.3: FFT result.

# Chapter 3

# Android App

The content of this chapter is to describe the app to get the heart rate of a person.The app developed is called **HR detector** and is based on Android operative system. In these lines we will explain how the **HR detector** application works internally and from the point of view of the user experience. The mobile device that has performed the tests and trials has been a Samsung Galaxy S4 LTE GT-i9505 16GB. Mention that to make use of the application, the mobile device must have mandatory front camera.

## 3.1 Inner workings

As mentioned above, this application is developed for the Android operating system, the company owned by Google. See Figure 3.1.a. The chosen IDE is eclipse with ADT (Android developer tools) package. See Figure 3.1.b. With this package will be possible to compile and debug during application development.

The **OpenCV** (open source) facilitates the task library for face detection. This library is written in C ++ and Java, last language has been used for the development of the app. **OpenCV** is a popular among professional image processing due to its variety of features and availability in different languages library. After the face detection and the detection of the forehead, we store it in a signal, the mean green channel of the pixels. It is normalized signal is filtered with a filter between 0.4 and 3 Hz. Once the signal is filtered use the Fast Fourier Transform (FFT) for frequency, and from there to get the heart rate (BPM). The signal to which it will perform FFT has contains 256 samples (frames). The result (BPM) will be displayed on a 'toast'. This method is useful to give instant information.

As is obvious, with better hardware, speed up the process of getting the heartbeat, because of the way the app is developed, reaching more number of frames per second (fps) we get the result in a faster way.

(a) Android logo

(b) eclipse logo

Figure 3.1: Android and eclipse IDE

## 3.2 User experience

The user experience begins with the previously installation of the app called **OpenCV Manager**. This application will provide our mobile device the necessary libraries to run our app. **OpenCV Manager** can be downloaded free from GooglePlay. Once you have installed the application **OpenCV Manager**, we can proceed to install **HR detector**. At this time we have ready the hardware and software.

To start the application have to click the icon itself, see Figure 3.2. By clicking the icon, the front camera is activated and can see on the screen what you are capturing. We must place the mobile device in landscape mode. We should leave the device in a place where it will not move. If this is not possible it is recommended to hold the phone with both hands to give greater stability.

Instantly our face is detected and can see a red box in our forehead. Inside this box it is where the 'data' necessary are taken to determine the heart rate. See Figure 3.3.

After a wait of about 8 seconds, depending on the power device, the result will be displayed, or in other words, the heart rate data. See Figure 3.4. After another eight seconds we will get a

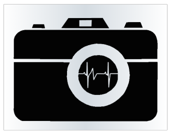

Figure 3.2: App icon.

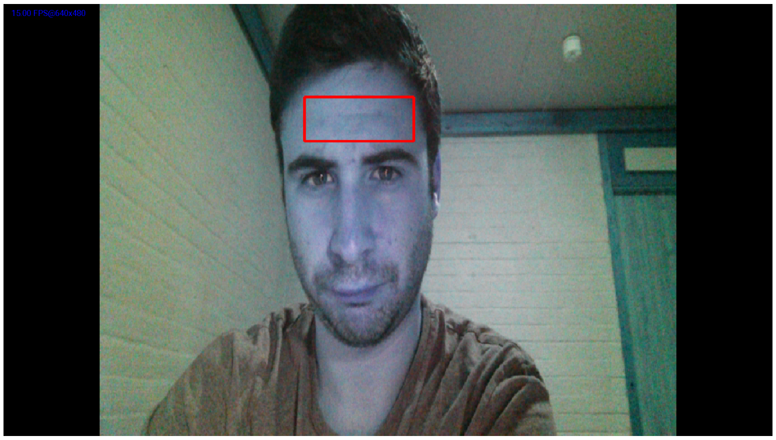

Figure 3.3: Forehead detected.

new heart rate data. If the user wants to leave the application you must press the "return" key once.


Figure 3.4: BPM.

# Chapter 4

# Summary and Recommendations for Further Work

## 4.1 Summary and Conclusions

Thanks to this project work I have learned about a technique such as the photoplethysmography. Combining the technique mentioned with the development of an app has been a challenge that I managed to develop new skills in Java and management of biomedical signals. The possibility of bringing anyone the ability to measure their heartbeat, with the camera of a mobile device we all carry over, I had not believed months ago.

Of course the result has not an accuracy of 100%, but after some improvements discussed in the next section, they can make an application with a high percentage of reliability.

## 4.2 Recommendations for Further Work

A good way to give more precision to the end result would be implementing a tracker so that the red box automatically follow our forehead. In this way we could obtain more reliable data of our skin and a more accurate result.

Another way to improve the application, not from a technical point of view, it would include the option to submit our results to a qualified person to the health sector, a doctor for example. First would be created one database registered with our results, then the results could be sent via email to our digital medical account. Medical personnel may have access to our data without the patient having to move to the health center or hospital.

# Appendix A

# Code

The code is hosted on **GitHub**, who want to see and use the code is enabled to do it.

**GitHub** https://github.com/maxim467/HR_project

# Bibliography

[1] M. Hirai, S. Nielsen, and N. Lassen. Blood pressure measurement of all five fingers by strain gauge plethysmography. *Scandinavian journal of clinical and laboratory investigation*, 36(7):627–632, 1976.

[2] Nave. Fft, 2006.