ANDROID-BASED IMPLEMENTATION OF EULERIAN VIDEO MAGNIFICATION FOR VITAL SIGNS MONITORING

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1. Motivation

Eulerian Video Magnification is a method, recently presented at *SIGGRAPH*[1] 2012, capable of revealing temporal variations in videos that are impossible to see with the naked eye. Using this method, it is possible to visualize the flow of blood as it fills the face [1]. Which provides enough information to assess the heart rate in a contact-free way using a camera [1, 2, 3].

Due to being recently proposed, the Eulerian Video Magnification method implementation has not been tested in smartphones yet. Thus, Fraunhofer Portugal is interested in testing the feasibility of implementing an Eulerian Video Magnification-based method on a mobile device with the Android platform.

There has been some successful effort on the assessment of vital signs, such as, heart rate, and breathing rate, in a contact-free way using a webcamera [1, 2, 3], and even a smartphone [4, 5].

Since it is a cheaper method of assessing vital signs in a contact-free way than the above products, this research work has potential for advancing fields, such as, *telemedicine*, *personal health-care*, and *ambient assisting living*.

Despite the existence of very similar products by *Philips* [5] and *ViTrox Technologies* [4] to the one proposed on this research work, none of these implement the Eulerian Video Magnification method.

2. Objectives

The main goal is to develop a lightweight, real-time Eulerian Video Magnification-based method capable of executing on a mobile device. Which will require performance optimizations and trade-offs will have to taken into account.

In the process, the creation of an Android application which estimates a person's heart rate in real-time using the device's camera will be developed.

3. Work description

In order to increase implementation speed and facilitate testing, a desktop application was first developed, which then was integrated into the Android application implemented.

The application was written in C/C++ with the aid of OpenCV library, an open-source image processing library. Hence, the integration with the Android platform was done through the Android Native Development Kit and the Java Native Interface framework.

The application workflow started by grabbing an image from the device's camera. A person's face was detected using the OpenCV object detect module which was previously trained to detect human faces. A region of interest (ROI) of the person's face would then be fed into the implemented Eulerian Video Magnification method to amplify color variations. The average of the ROI green channel was computed, in order to increase the signal-to-noise ratio, and stored. Along the time, these stored values represent a photoplethysmographic [6] signal of the underlying blood flow variations. The signal is further processed using the detrend method [7] to remove trends from the signal without magnitude distortion. It is then validated as a cardiac pulse signal by detecting its peaks in order to verify its shape and timing. Finally, the heart rate estimation is computed by identifying the frequency with the higher power spectrum of the signal.

3.1. Eulerian Video Magnification

The initial implementations of of the Eulerian Video Magnification method were written in Java. However, because OpenCV Java support was still recent and due to performance reasons the final implementation was written in C/C++.

The Eulerian Video Magnification method approach combines spatial and temporal processing to emphasize subtle temporal changes in a video. First, the video sequence is decomposed into different spatial frequency bands. Because they may exhibit different signal-to-noise ratios, they may be magnified differently. In the general case, the full Laplacian pyramid [8] may be computed. Then, temporal processing is performed on each spatial band. The temporal processing is uniform for all spatial bands, and for all pixels within each band. After that, the extracted bandpass signal is magnified by a factor of α, which can be specified by the user, and may be attenuated automatically. Finally, the magnified signal is added to the original and the spatial pyramid collapsed to obtain the final output.

In this work, amplification of color variation was more important than motion magnification. Thus, the spatial filter used was the computation of a Gaussian

[1] `http://www.siggraph.org/`

pyramid level, which consists of applying a Gaussian blur filter and downsampling the image multiple times. However, because performance was a priority and computing a Gaussian pyramid level was computationally expensive, this step was changed to a single resize operation using the interpolation method *AREA* of the OpenCV library, which produces a similar result to the computation of a Gaussian pyramid level.

Temporal filtering is used to extract the motions or signals to be amplified. Thus, the filter choice is application dependent. For motion magnification, a broad bandpass filter, such as, the butterworth filter, is preferred. A narrow bandpass filter produces a more noise-free result for color amplification of blood flow. An ideal bandpass filter is used on [1] due to its sharp cutoff frequencies. Alternatively, for a real-time implementation low-order IIR filters can be useful for both: color amplification and motion magnification. Therefore, the subtraction of two low-order IIR filters were used in the Eulerian Video Magnification method implemented.

3.2. Heart rate estimation

The heart rate estimation is computed using the *Fourier transform*, which is a mathematical transform capable of converting a function of time, $f(t)$, into a new function representing the frequency domain of the original function.

To calculate the power spectrum, the resulting function from the *Fourier transform* is then multiplied by itself.

Since the values are captured from a video, sequence of frames, the function of time is actually discrete, with a frequency rate equal to the video frame rate, FPS.

The *index*, i, corresponding to the maximum of the power spectrum can then be converted into a frequency value, F, using the equation:

$$F = \frac{i * FPS}{2N} \tag{1}$$

where N is the size of the signal extracted. F can then be multiplied by 60 to convert it to beats per minute, and have an estimation of the heart rate from the extracted signal.

4. Conclusions

An Android application, named Pulse, which was capable of estimating a person's heart rate using the Eulerian Video Magnification method was developed.

A lot of effort went into improving the application performance, so it was able to execute on an Android device. Having a performance increase of 22% from the initial implementation, as suggested by [1], to a performance optimized version.

Because of this the application heart rate estimations accuracy was low. The Pulse application measurements from 9 participants were compared to the readings of a sphygmomanometer. The agreement between the two according to the Bland-Altman plots analysis had a mean bias of -12.00 with 95% limits of agreement -33.13 to 9.13 bpm.

4.1. Future work

Having developed a lightweight, real-time Eulerian Video Magnification-based method for the Android platform which goal is to amplify color variations, the performance of different variants of the Eulerian Video Magnification method could be improved. Leading to increase the usage of this method in all kinds of devices.

The implemented Pulse application needs to improve its heart rate estimations accuracy, and different monitored vital signs could be added, such as, breathing rate.

To support some features of the implemented Android application, Pulse, part of the *OpenCV for Android SDK* library had to be modified. These change can be contributed back to the community, since the OpenCV support for the Android platform is still in its early stage.

References

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