Non-contact Heart Rate Measurements using Video Imaging

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Overview

- Why Non-contact?
- Why using Video analysis?
- Eulerian Video Magnification Method?
- What is Independent Component Analysis?
- What is Photo-plethysmography(PPG)?
- Proposed Approach?
- Testing Technique?
- Results?

Introduction

- Non-contact medical devices play a significant role in monitoring the health of the individual.
- Human heart rate is one of the most important and commonly measured parameter used to know the medical condition of an individual.
- The current methods for monitoring these parameters are invasive, expansive and not portable, most of them typically require patients to strap sticky electrodes, bulky sensors and chest straps and on their bodies.

Recent Works

Figure : Traditional methods for measuring heart beat.

- Some of the earliest works for measuring cardiac pulse include using piezoelectric measurements [4] thermal imaging [1], Optical phenomenon[2] and using Principal Component Analysis[3].

Eulerian Video Magnification

- It is method to obtain subtle changes in motion, colour etc...
- Basic Approach: Given a video sequence as an input, we analyze the color variation in each pixel over time and amplify the variation and add back to the original video which results in a magnified version of the video.

Eulerian Video Magnification

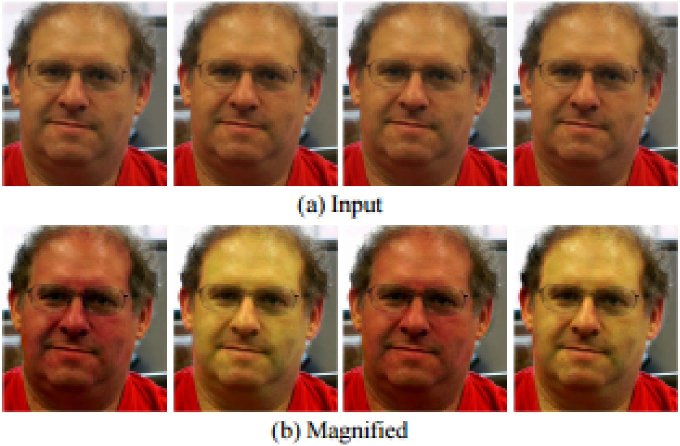


Figure: Example of an EVM

Eulerian Video Magnification

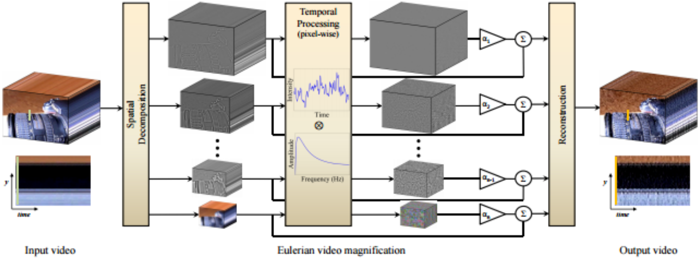


Figure: Overview of an EVM

Mathematical Viewpoint

- Intensities at time 0 and time t be

$$I(x, 0) = g(x)$$

$$I(x, t) = g(x + d(t))$$

  where d(t) is displacement vector

- By Taylor series expansion,

$$I(x, t) = g(x + d(t)) = g(x) + d(t)g'(x)$$

Mathematical Viewpoint

- Let the signal obtained from the temporal filter be A(x, t). We have to choose the cut off frequency such that d(t) is in the pass band of the filter. Then A(x,t) can be expressed as,

$$A(x,t) = d(t)g'(x)$$

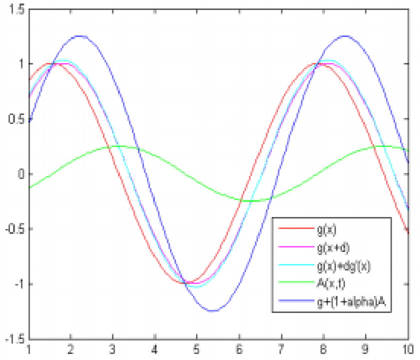
- Now A(x,t) is amplified by a factor of α and added back to original signal resulting in

$$\hat{I}(x,t) = I(x,t) + \alpha A(x,t)$$

$$\hat{I}(x,t) = g(x) + (1+\alpha)d(t)g'(x)$$

$$\hat{I}(x,t) = g(x + (1+\alpha)d(t))$$

Mathematical Viewpoint



If we can't find the cutoff frequency to fit the whole of d(t), then we deal with components of d(t) with new amplification factor $\alpha_k = \alpha\gamma_k$

$$A(x,t) = \sum_k \gamma_k d_k(t) g'(x)$$

Results

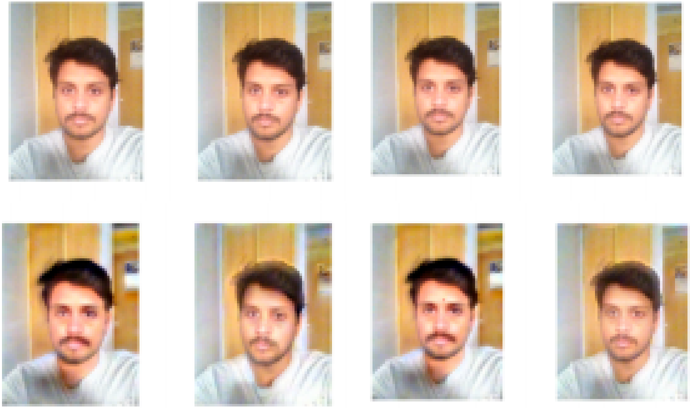
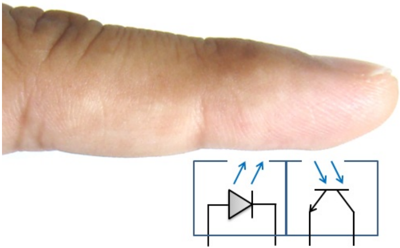


Figure: Results of EVM

Photo-plethysmography - PPG



- PPG is based on the concept of measuring changes in reflection of light because of volumetric changes in concentration of blood.
- This change in light can captured using a camera and a measure can be used to quantify various health parameters.

Independent Component Analysis - ICA

- ICA is a type of blind source separation method where we do not know the source signal and we try to find the sources responsible from a large number of observed signals that are composed of linear mixtures of the underlying sources.
- Let the observed signals be y_1, y_2 and y_3 and let the underlying source signals be $g1$, $g2$ and $g3$. The ICA assumes that observed signals are a linear mixture of sources :

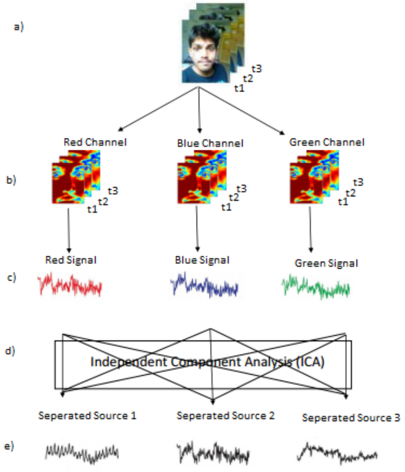
$$y_1 = g_1 * a + g_2 * b + g_3 * c$$

$$y(t) = B * g(t)$$

  where a,b,c are some variables and y and g are the column vectors y(t) = $[y_1(t),y_2(t),y_3(t)]^T$ and g(t) = $[g_1(t), g_2(t), g_3(t)]^T$
- The goal of ICA is to find a approximation of de-mixing matrix A which is the inverse of the signal mixing matrix B as follows:

$$\hat{g}(t) = A * y(t)$$

HR Measurements using ICA approach



Experimental Setup

- All measurements were performed with minimal light conditions. They were performed indoor with sunlight as only source of illumination.
- All the videos were recorded at 29 frames per second in 24-bit at a resolution of 640x480 pixels.
- Each video was taken for a duration of 10 seconds. So, each video recorded consisted of 240 frames.
- The analysis and processing of data has been done using MatlabR2012b.

Procedure

- The video is first read into the application and the Region of Intrest(ROI) is extraced from the video. The area between the eyebrows and the nose is selected as the ROI.

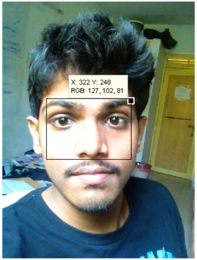


Figure: ROI Extraction

Procedure - Continued

- The ROI was further separated into red, green and blue channels and spatially averaged over all the pixels to yield a single measurement for each frame(x_r(t),x_g(t),x_b(t)).
- The RGB traces were further normalized as follows :

$$x_i'(t) = \frac{x_i(t) - \mu_i}{\sigma_i}$$

  Where i = {r,g,b} and μ_i , σ_i are the median and standard deviation of the signal $x_i(t)$ respectively.
- These smoothed raw traces were decomposed into three independent source signals using ICA. We have used JADE algorithm for calculating the underlying source signals.

Procedure - continued ...

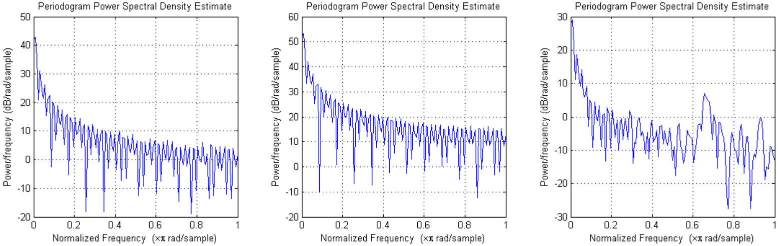


Figure: Example - Three underlying source signals after ICA

- The ICA procedure will produce three independent source signals.
- The one which contained the highest peak in the power spectrum was selected and given for further processing.

Quantification of Heart Beat

- The extracted source signal was smoothed using a 5 point averaging filter.
- The signal was further band pass filtered using a Hamming Window filter of size 128 between 0.7 and 4 Hertz.
- This signal was interpolated using cubical spine function at a frequency of 256 Hz.
- The peaks of this signal were analysed to find average of inter-beat intervals(IBI) which is divided upon 60 to get the actual heart beat.

Quantification of Heart Beat

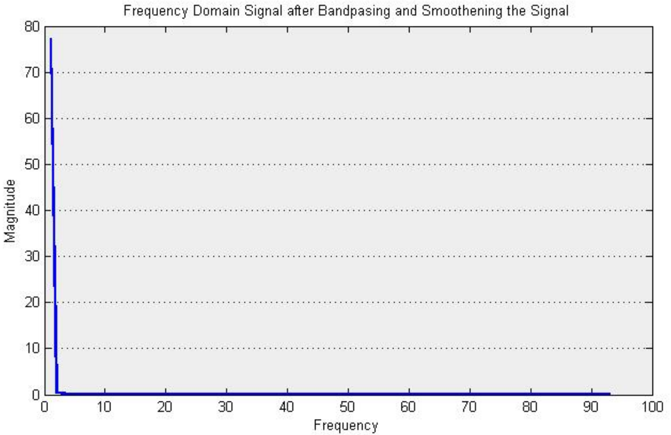


Figure: Frequency domain signal after the interpolation.

Algorithm

1. Load the Video and extract the ROI.
2. Decompose the Video into RGB Channels.
3. Average each channel on entire frame and normalise the signal.
4. Apply Independent Component Analysis on the three signals.
5. Convert the source signals into frequency domain and select the signal having the highest peak.
6. Apply a five point smoothing filter and bandpass the selected signal between range 0.7 to 4 Hz.
7. Apply Cubical Spine Function at a frequency of 256Hz to the band passed signal

Results

- Cardiio, an application developed based on the research in MIT Media labs, has been used to compare the results.
- Cardiio is a very popular application available on app store, which calculates the heart rate based on principle of light reflection using the concept of photoplethysmographic(PPG) signal.

Results

- The experiment was conducted among a sample data set of 10 videos of students of DAIICT. The results obtained were given the table 1.

Table: Experiment Results

Experiment	Observed Value	Actual Value
Data 1	68	72
Data 2	65	63
Data 3	60	64
Data 4	82	78
Data 5	75	70
Data 6	55	62
Data 7	62	61
Data 8	77	79
Data 9	80	75
Data 10	72	70

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References

- Garbey,Merla, Sun, and Pavlidis, "Contatct - free measuremnt of cardiac pulse based on analysis of thermal imaging" IEEE Trans. Biomedical Engineering volume 54, issue no 8 , page no. 141826
- Ulyanov, Tuchin, "Pulse-wave monitoring by means of focused laser beams scattered by skin surface and membranes" 1993, SPIE, vol no 1884, page no 1607
- M. Lewandowska, J. Ruminski and T. Kocejko Measuring Pulse with a Webcam a Non-contact Method for Evaluating Cardiac Activity, IEEE pageno : 40510, 2011.
- Aminian, Thouvenin, Robert, Seydoux and Girardier, "A piezoelectric belt for cardiac pulse and respiration measurements on small mammals," Engineering in Medicine and Biology Society, volume no 6, page no : 2663-64, 1992

References

M.Z. Poh, McDuff, and Picard. Non-contact, automated cardiac pulse measurements using video imaging and blind source separation. Optics Express, 18(10):1076210774, 2010.

Hao-Yu Wu, Michael Rubinstein, Eugene Shih, John Guttag, Frédo Durand and William T. Freeman, Eulerian Video Magnification for Revealing Subtle Changes in the World, ACM Transactions on Graphics (Proc. SIGGRAPH 2012),volume : 31, number : 4,

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