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A Non-Contact Method for Cardiac Pulse Measurement with Smart Phone: Client-Server Architecture

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Abstract. Heart rate is recognized as a free hazard outline for cardiovascular illnesses. In this paper, we have implemented an interesting method for heart rate measurement, which is based on blind source separation of human face video captured using smart phone with three color channel signal. Performed statistical analysis for noise elimination and separated required signals for further processing. For reducing processing at mobile side, client-server architecture is implemented as smart phone – server – smart phone. Heart rate is computed using fast Fourier transform (FFT) on principal component's (PC) on server, finally the result (i.e., heart rate) will be displayed on mobile through the client interface.

Keywords: heart rate measurement, blind source separation, client server architecture, fast Fourier transforms

1. Introduction

In current social order, an expanding number of individuals are experiencing cardiovascular calamities. Resting heart rate (Hr) is one of the least difficult cardiovascular parameters. Hr measurement is very important for those persons suffering from heart diseases [1]. In this paper, we depict a remote, non-contact and non-obtrusive technique to advantageously measure human heart rate. Few non-contact estimation systems are proposed based on image signal processing algorithms Keeping in mind the end goal to measure the heart rate concurrently, Chihiro and Yuji in [2] improve a non-contact apparatus by applying autoregressive(AR) ghastly examination to a period failure picture.

Photoplethysmography (PPG) is an additional system that is being utilized within identifying beat rate [3]. It uses updates of the optical lands of a chose skin zone included by throbbing blood substance. The common execution of PPG uses committed light sources, e. g. close infrared light. Updates of the light power reflected from the skin compare to a volume of tissue blood perfusion. Also, it has been demonstrated that HR estimation from human face is additionally conceivable utilizing sunshine as the enlightenment source [4]. Poh et al. has improved a strong strategy for processing of the heart rate from advanced color movie recordings of the human face [5,6]. In [5,6], Ming-Zher et al. use face discovery and Independent Component Analysis (ICA) to break down a webcam caught front side recording, and acquire the cardiovascular beat estimations.

A principal component analysis (PCA) is utilized within our procedure. It is applied to RGB channel of face video and as a result it lessens computational intricacy in correlation to independent component analysis (ICA). We likewise demonstrate that it is conceivable to figure out a beat rate dependent upon minor rectangular area of the face picture and just on two shade channels. It is significant when acknowledging computational effectiveness of the home human services observing framework and its operation progressively.

The vast majority of the existing calculations are realized on PC or wired apparatuses, which are non-versatile and along these lines badly designed. Our object is to understand the non-contact cardiovascular beat estimations on a conveyable gadget. We first accomplish the calculation of HR using ICA and PCA on a PC by consistently taking facial pictures and concentrating the comparing HR utilizing Image processing.

After comparing results, we implemented the accurate and optimized method in Android app. In light of the more and more improving market of versatile smart phones, we then make the requisition compact by utilizing Client/Server architecture for an Android smart phone.

2. Methodology

Compared to other languages, Arabic has a rich morphological variation and inflectional syntactic characteristics extremely complex, which is one of the main reasons for which [9][22] explains the lack of research methods in the field of treatment of Arabic.

A. Experimental setup for PC:

In the Pc variant, we customized a C++ script to catch images from the Laptop webcam. The caught images were straight sent to the image processing system. After each 10 images were handled, the effects were come back to the MATLAB post-processing system as a 10x3 network. The catching speed of this technique was around 10 to 15 frames per second (fps) and the determination of the caught image could be as high as 640x480.

B. *Experimental setup for Mobile:*

In the mobile variant, we enabled a android API to catch images from the mobile's camera. To upgrade the data communication rate, images were encoded as JPEGs and each five images caught were added into a data file to be sent in one association. Additionally, we utilized 5 communication threads to send data file in asynchronous mode. The final speed greatly relied on upon the system. For the most part, it could catch and send five 320x240 casings for every second.

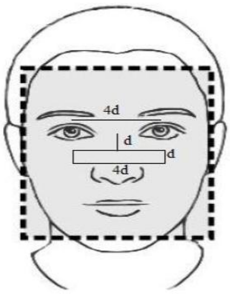


Figure1: Two ROI’s used, namely, (i) full face (i.e., rectangle with dotted lines) and (ii) part of nose and cheek (i.e., small rectangle over nose with solid lines)

C. *ROI selection:*

We did our experiment for two diverse ROI's (regions of interest) sizes. Firstly, we choose the rectangle box with the full part of the face-frame (Fig. 1) Coordinates of chose face part continued as before for the entire grouping of images. We have chosen a rectangle-box containing part of nose and cheek as second ROI. It was characterized based on coordinates of both eye’s center and distance measured between them. We can see both ROIs in figure 1. Firstly, we compared results of both ROIs then we implemented analysis on ROI for which results are better. ROI selection in face video is done using Viola & Jones face detection algorithm which is very robust in nature [7, 8].

All the pixels in the face in every channel of a frame is summed to obtain three RGB raw sample points, which are then arranged sequentially to form three RGB raw traces. Note that these raw data are not necessarily stationary. During our signal processing procedure, only stationary segments could be analyzed so we normalize all the raw channels. To solve this problem, the three raw traces are detrained based on a smoothness priors approach, with a regularization parameter λ = 10 (corresponding cutoff frequency is 0:059fs). RGB channels are shown in figure 2. The raw traces in the RGB channels are then normalized as follows:

$$x_i(t) = \frac{r_i(t)-\mu_i(t)}{\sigma_i}, \text{ where i= 1,2,3} \quad (1)$$

Where μ_i and σ_i are the mean and the standard deviation of $r_i(t)$. Raw traces of normalized RGB channel are shown in figure 3 .

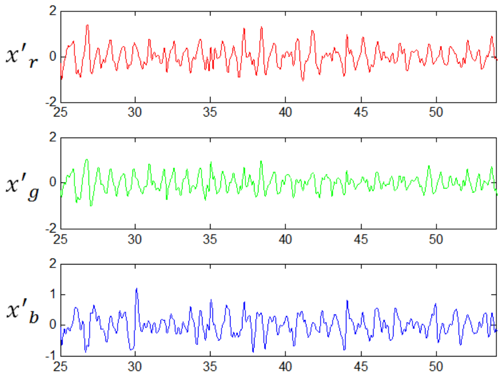


Figure 2: Raw RGB traces

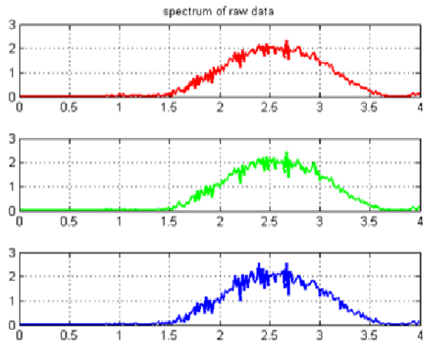


Figure 3: spectrum of Normalized RGB traces

For comparison purpose, we did our experiment with two analytical methods, namely, (i) Independent component analysis (ICA) and (ii) Principal component analysis (PCA) on earlier mentioned two different ROIs and utilized that algorithm in mobile application which gives best result in PC version application.

D.Analytical Method:

Independent Component Analysis (ICA) is used in measurable and calculation methods to extract independent components from a set of signals which are part of mixtures directly from the detected source. [9] ICA method supposes that the detected signals Q (t) are just linear mixtures of P (t) which is unknown source:

$$Q(t) = A.P(t) \quad (2)$$

A is the mixing matrix which is not known. To gauge both A and P(t), components of a vector P is the hope that it will be a non-Gaussian distribution and are statistically independent. After evaluating the matrix A, it was possible W (the demixing matrix) which is inverse of A, to be processed. There is likely to be acquired independent components at that time:

$$P(t) = WQ(t) \quad (3)$$

To compute the demixing matrix W, various methods are given. In our paper, we implemented Fast ICA method [10].

The Principal Component Analysis, (PCA), which is a procedure regularly utilized for data reduction as a part of statistical pattern recognition, image processing and signal processing. The PCA is a tool that is used for identifying data patterns, and results the differences and similarities between same types of data. That's why PCA is a capable instrument for data analysis [11].

The fundamental thought in PCA is to discover the components p1; p2;…. sn with the goal that they demonstrate the greatest measure of difference conceivable by N directly changed components. The essential components are then given by $p_i = w_i{}^T . x$. The processing of the w_i could be fulfilled by utilizing the covariance matrix $E[x . x^T] = Q$. The vectors w_i are the eigenvectors of Q that compares to the N biggest eigen values of Q.

These components ought to be requested in a way so that the to begin with segment, p1, indicates in the direction where the inputs are having the maximum variance. The second principal component is orthogonal to the first component and focuses toward 2nd highest variance after first principal component.

Assume we have two arbitrary vectors, R and S, with zero mean so that E[R] = 0 and E[S] = 0. Let V signify an unit vector, onto which the R will be projected. This projection is characterized by the internal result of the vectors R and V, as demonstrated by:

$$S = V^T R \tag{4}$$

Here V is an orthogonal matrix. Columns of V are principal components and they are considered by pointing for the direction of greatest data variance. Each and every PC is orthogonal to rest other PC. Columns of V, which are covariance matrix's eigen vectors requested in decreasing order [12].

For each ROI's channel, total of pixel values was calculated for every frame. The signals acquired along these lines were sifted utilizing a FIR band pass channel utilizing *Matlab* "*Fdatool*". Next, we performed ICA and PCA. "*FastICA*" function in *Matlab* for implementing ICA. We computed Principal components with the utilization of *Matlab* "*processpca*" function.

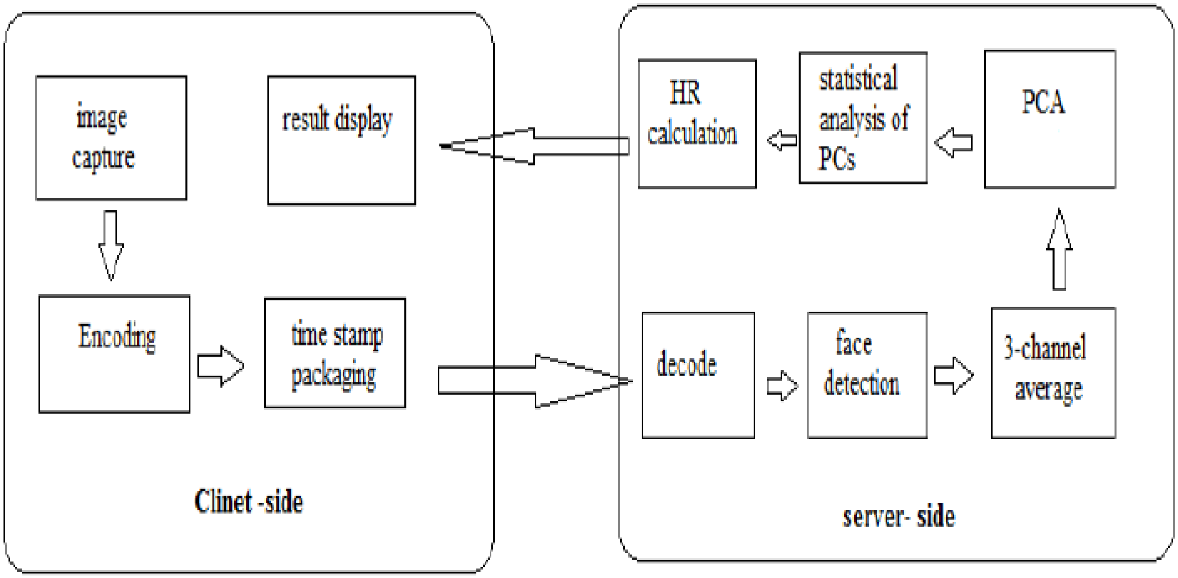


Figure 4: Structure and data flow for mobile application

Figure 4 shows the framework structure of our HR estimation application for smart phone. In the figure Client side is Mobile application and server side is my Laptop connected using wireless network.

In the client showed in figure 4, a human face picture is initially recorded by smart phone camera. For portable application, it is encoded and stamped by time (Note: timestamps are utilized to figure the examining rate of the mobile camera as f = Number of frames recorded in particular time duration in Hz). Each 5 successive frames are bundled and transmitted to the sever terminal by means of remote system. The sever might as well first interpret the signal. It executes all the post-processing calculation of PCA and statistical analysis, it transmit the estimated HR value to the client. At last, the evaluated HR is shown in the mobile application screen simultaneously with recording face video.

3. Results and Discussion

ICA and PCA is performed on both ROIs, complete face and rectangle nose centered part. Time complexity and pulse count results of PCA is compared with as of corresponding ICA. Our observations are listed as follows:

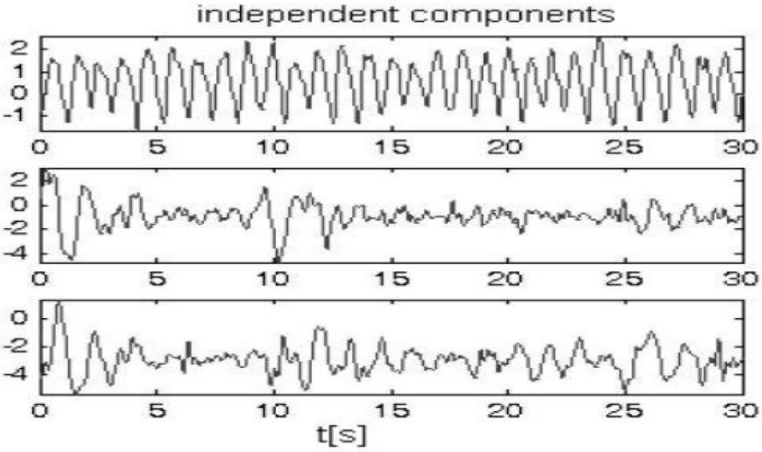
- Computation time of ICA for face ROI and nose centered ROI was 220-227ms and 90-96ms respectively, while computation time of PCA for both ROIs was 1.6ms and 1.3ms, almost in real time scenario. So the computation complexity of PCA is much less than ICA, i.e., time complexity reduces considerably.
- For heart rate (i.e., pulse rate) estimation, we compute the power spectral density of all independent components and selected the component with highest power spectral density for HR estimation and computed fast Fourier transform of IC and PC. Finally implemented the best algorithm in mobile application.

- To compare pulse rate obtained from ICA and PCA with the real pulse rate, we measured real pulse rate at the time of recording with another Cardiac gadget (CG) and compare the result in table 1. From this table it is evident that PCA approach is slightly better than the ICA for face ROI and nose rectangle ROI in term of both relative and absolute errors form the actual pulse.

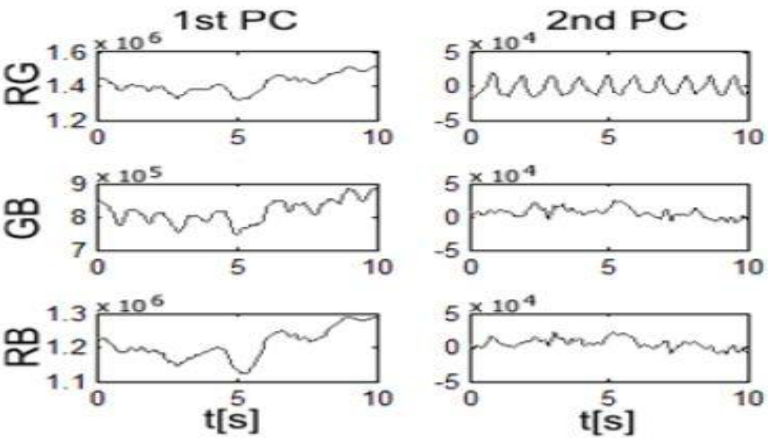
Table 1: A comparison of pulse rate measure in different schemes

Video number	**Pulse rate using (CG)**	**Pulse using ICA (face ROI)**	**Pulse using PCA (face ROI)**	**Pulse using PCA (nose rectangle ROI)**
1	60	57.67	61.32	60.56
2	72	69.67	71.33	72.21
3	88	90.04	90.12	89.23
4	59	59.03	58.4	60.01
5	100	101.2	100.54	99.81
6	103	97.11	98.13	100.23
7	49	43.56	47.34	48.11
8	57	60.01	59.01	58.33
9	78	80.23	80.02	79.34

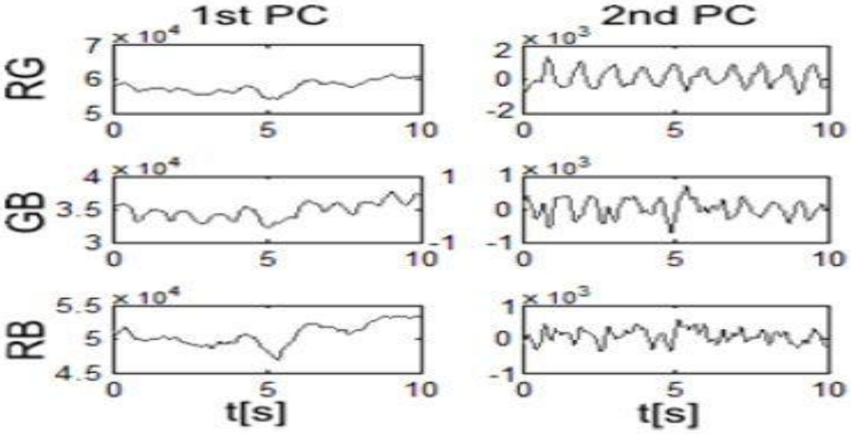
- The behaviour of three independent components resulted from ICA of RGB signals of face ROI are shown in figure 5 and it is observed that the behaviour of first IC is almost similar to heart pulse signal.
- The point when processing signals from just two channels, discovery of pulse was best when we were considering RG combination (figures 6 and 7). Nonetheless, contrasted with the examination utilizing three channels the "beat" segment (2nd PC) was more similar as real heart rate distortion, particularly when nose rectangle ROI was analyzed (figure 7).



- Figure 5: Three IC's resulted from ICA of Face



- Figure 6: PCs for RG, GB and RB channel combination for face ROI



- Figure 7: PCs for RG, GB and RB channel combination for nose centered rectangle ROI

4. Conclusion

In our paper, we have implemented an interesting method for heart rate measurement through image processing. After recoding face video using mobile camera, frames are packaged and encoded in suitable format after that they are transmitted to server side, on server side data packet is decoded and face detection algorithm is implemented to get the region of interest, the difference sequence of ROI is used to get RGB data. We implemented both PCA and ICA in PC version for comparing results.

Accuracy of results obtained from ICA and PCA is approximately similar, but computation time for PCA is very lower than that of ICA. This method is decreasing computation time. That’s why we implemented this algorithm in Mobile application. Accuracy of HR estimation in Mobile application will approach PC version in ideal network conditions. Results may be better in Mobile application if Good quality camera is used in mobile phone.

A simple processing of image data and then applying PCA allows extracting the changeable component containing information of the heart rate, which is correct upto 99%. The presented algorithm seems to be quite effective and easy to use in the daily monitoring of home care patients. However, a further study has to be performed on moving persons and the same with more than one camera.

5. References

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