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Heart Rate Detection Using Independent Component Analysis and Multivariate Adaptive Regression Splines

Dr. Simmi Dutta[1], Hiteshwar[2], Abhimanyu Dev Jamwal[3] & Azhar ud din Guroo[4]
[1,2,3,4] Government College of Engineering and Technology, Jammu

Abstract- *In this paper we describe a heart rate detection system that improves up on the existing heart rate detection system that uses independent component analysis by adding a regression system. The system has been trained using multivariate adaptive regression splines by taking actual accumulated data values and the values obtained by analysing components extracted from facial features.*

I. Introduction

Heart rate is one of the essential parameters in most of the medical diagnosis techniques for numerous medical conditions. Earlier detection of heart rate involved counting of heart pulse by either holding the person's hand or by attaching a machine having a heart rate sensor to person's body part over a vein. In previous few years numerous systems have emerged that are able to extract heart rate by non-contact methods by analysing the minute movements of facial features that happen as the blood is pumped into our head. These moments are so small that they cannot be observed by naked eye so we apply sophisticated computer vision algorithms to detect and analyse these moments and from them we are able to extract the heart rate. But this heart rate is not accurate with errors ranging from 60 % to 90 %. To remove these errors, we have developed this system that uses a corrective model produced by applying multivariate adaptive regression splines on the data that we accumulated by recording the heart rate by both contact less computer vision and also from the actual heart rate sensor of a wrist based medical device available in the market.

II. System overview

The basic components of the system are as follows:

1. Continuous Image Capture.
2. Face Detection.
3. Facial Component Extraction and RGB Average Calculation.
4. Independent Component Analysis
5. Peak Detection and recording.
6. Preliminary Heart Rate Calculation.
7. Error Adjustment by Regression Model.
8. Final Heart Rate Generation.
9. Results

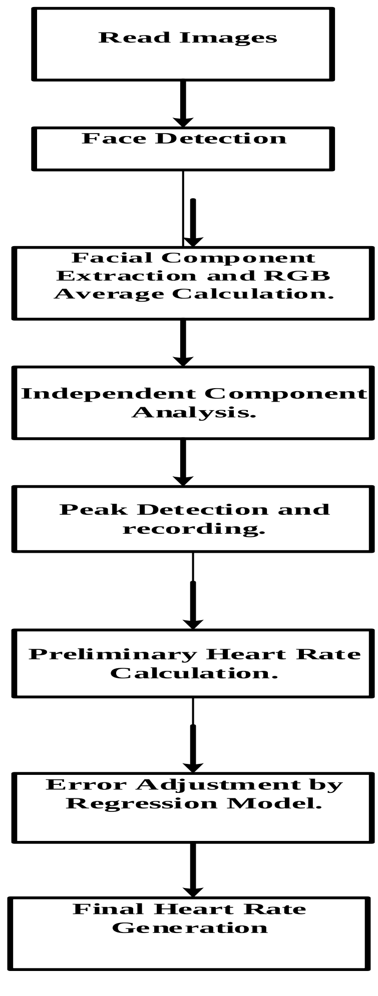

Fig. 1. Overall system flow showing processes running on the user end and on the server.

The overall system consist of mainly three sub systems. The first stage captures the facial images are captured at a continuous rate n interval, while the second applies image analysis is applied to detect face and facial features and extract their RGB components and third is analyses of these components to generate the heart rate and applies regression on it to generate the actual rate. The whole system is implemented in Matlab using its native functions and some part is implemented in C++ that uses OpenCV (3.0.0) library.

III. Continuous image capture

A simple C++ program using OpenCV (3.0.0) library is used to capture images this program is used in Matlab by using its MEX feature.

IV. Face Detection

We used OpenCV to obtain the coordinates of the person's face using algorithms as describes in [1]. This analysis results into cropping of whole image into a small square image that contains the persons face only.

V. Facial Component Extraction and RGB Average Calculation

After the face is detected we define a region of 70% width and 85% the height of the image as the region of interest to extract components from the image. Here the complete RGB values of all the components are summed to generate a raw trace. This raw data is then de-trended to remove any irregularities and to obtain a stationary plot using the method suggested in [2]. Then, the RGB trace obtained after de-trending is normalised using the following:

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

Where

μ_i = mean of r_i(t)
σ_i = standard deviation of r_i(t)

This resultant data is then plotted by using Welch's method to obtain a power spectrum as shown in Fig.X.

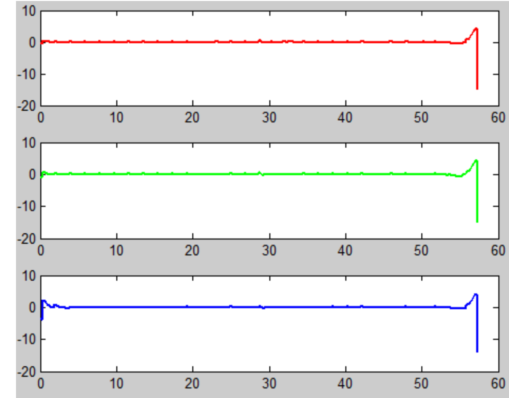

Fig2. Power spectra Plot of normalised RGB traces

VI. Independent Component Analysis.

Now as we have to further understand the movements of the de trended normalised RGB component traces, we applied independent component analysis. The independent component analysis that we are going to use is based on the technique suggested in [8] called joint diagonalization of cumulant matrices JADE. The RGB traces are fed into the JADE and 3 signals are obtained that are separate from one another. These separated signals are shown in fig. [3]. then the spectral magnitudes of these signals is also obtained by same method as discussed earlier and is sown in fig. [4]. these separated signals are also smoothed using a low pass filer and a bandwidth of 1-4 Hz.

VII. Peak Detection and recording

The pulse values is the happening of peak in the separated signals. We applied the Continuous Wave Transform Algorithm for detecting the peak and accept it as the occurring of blood pump pulse

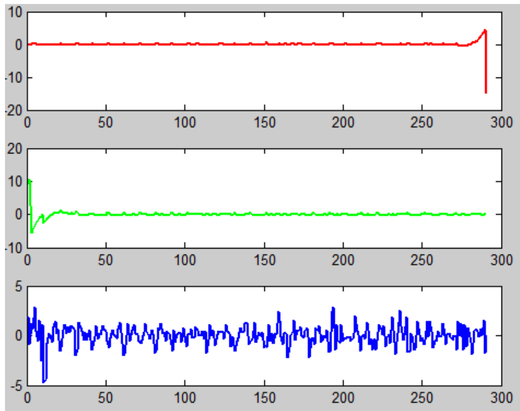

Fig 3. Plot of independent traces obtained by ICA, JADE.

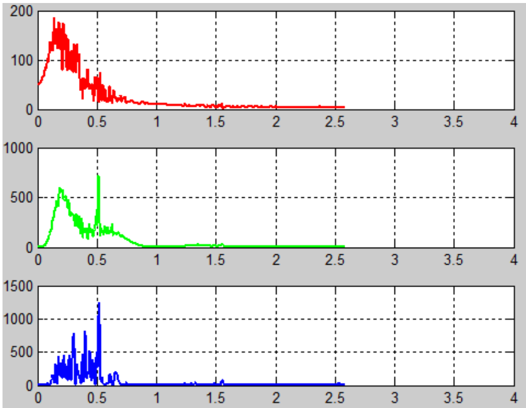

Fig 4. Plot of Magnitude of independent traces.

VIII. Preliminary Heart Rate Calculation

As, we have calculated the blood pulse the heart rate is estimated as 60 × blood pump pulse from peak detection. However this is prone to errors.

IX. Error Adjustment by Regression Model

The preliminary heart rate thus obtained is fed into the model that was trained by using the MARS [7] by us. This model adjusts the obtained heartrate for various anomalies and errors that may have crept into the system during the process taking into account the historical data and various other factors like capturing conditions, computational assumptions and data inconsistencies. For all such conditions various weights are added and final value is obtained.

MSE	16.0059	16.0059	16.0059
GCV	16.3893	16.3893	16.3893
coefs	[74.0404;-0.2322]	-0.2322	74.0404
knotdims	<1x1 cell>		
knotsites	<1x1 cell>		
knotdirs	<1x1 cell>		
parents	0	0	0
trainParams	<1x1 struct>		
t1	73.5000	73.5000	73.5000
t2	83.5000	83.5000	83.5000
minX	68	68	68
maxX	88	88	88
isBinary	0		

Fig. Regression model obtained by Mars

X. Final Heart Rate generation

Finally the heart rate calculated after adjusting for various factors is displayed on the screen of the user as number of beats per minute.

XI. Experiment Setup and Results

The users were asked to sit in a well-lit environment on a chair in the front of a HP laptop running Matlab and Visual Studio 2013 with OpenCV (3.0.0) on Windows 10 platform with Intel Core i5 (5^{th} Gen) 2.2GHz Processor and 8G GB of Ram and 2 GB NVIDIA 950m Graphics Processor with a 1.3-megapixel inbuilt webcam as an image capturing device. The images were taken in 24bit- RGB format at 15 fps with a resolution of 640 × 480. The results obtained by our system with the Accuracy of 97% ±1.5.

XII. Conclusion

In this paper we described a heart rate detection system that improved on the existing heart rate detection systems that used independent component analysis by adding a system that has been trained using multivariate adaptive regression splines by taking actual accumulated data values and the values obtained by analysing components extracted from facial features.

The future work for this system include developing a standalone web, desktop and mobile applications and also to improve upon the accuracy of the system by improving the blood pump pulse detection and by refining the regression model by taking into account an even larger dataset.

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