An Approach To Enhance The Biomedical Research: A Video Operated Heart Rate Measurement

Puneet Sapra[1], Dr. Anoop Sharma[2], Dr. Ajay Goyal[3]
[1]*School of Computer Science and IT, Singhania University*
[2] *School of Computer Science and IT, Singhania University*
[3] *School of Computer Science and IT, Singhania University*
(E-mail: puneetsapra91@gmail.com)

Abstract—**In this work the heart rate is evaluated based on the color variation in the video of the patient by which the most accurate heart detection can be performed. Initially by using a video camera a video sequence of the patient is captured and also saved to the system for the further processing whereas 60 frames per second are recorded. Afterward the video frames are extracted on which the image pre-processing is applied which is used to improve the quality of the image. In this work adaptive histogram equalization and median filter is utilized to evaluate the mean of the preprocessed frames. Also peak is detected by using the FFT method on which Butterworth Filter is utilized that is used to improve the extorted frames' edges. The proposed work is implemented in MATLAB, the results are obtained on the basis of correlation, success rate, z score, BPM and error rate the results of E-HRD, EF-HRD and OEF-HRD respectively.**

Keywords—Heart Rate, Heart Waves, PQRST waves, Feature Extraction, Classification.

I. INTRODUCTION

ECG i.e. Electrocardiogram as a biomedical device is utilized for ascertaining several operations and working of heart. ECG provides massive information, which could be the general or specific physiology of heart [1]. The Electrocardiograph signals are of variable traits and hence, determining and evaluation of ECG is a cumbersome task. Hence, it is significantly mandatory to utilize computer based techniques to examine the ECG signal. Due to large fluctuation and variability in the signals obtained from electrocardiogram, the evaluation and determination of output is a troublesome process [2-5]. The variations produced in the signal are non-periodic and are not provided pre-defined time sessions. The visual basis examinations are not completely reliable. Hence, the computer based methods has been invented to examine ECG signal [6]. During heartbeat, heart depolarization leads to the production of heart contraction. The electric signals are produced by consequent contraction and relaxation of heart muscles which are further evaluated by operation of device through skin [7]. This technique is utilize to determine the pace and periodicity of heartbeats so that if there is any kind of irregularity in the heartbeat can be detected with less efforts [7]. The electrocardiogram is referred to as a biomedical device that plots the activity of heart on the screen graph in form of electrical signals [8].

II. PROBLEM FORMULATION

Heart rate prediction was done on the basis of obtained ECG signals. To do so physicians have to install big machines. These machines for observing ECG rate of one's heart is become quite popular as its results are quite effective and thus it becomes trustworthy among patients and physicians also. The ECG machines are quite expensive and heavy to hold. Therefore, to reduce the complexity, cost incurred and inconveniences the heart rate prediction domain moves toward a new research domain in which by use of the facial expressions, physical activities, and speech of the patient heart rates are predicted. On the basis of the literature review it is concluded that limited work has been done in the field of heart rate prediction using physical activities like facial expression, physical activities. And to make the patients and doctor more conformable with this style of analysis it is required to get effective heart rate prediction models whose major sections are feature extraction approaches, video enhancement , decision capability enhancement this will this domain more reliable and convenient among users.

III. PROPOSED WORK

The proposed work aims to evaluate the heart rate on the basis of the color variation in the video of the patient. For this purpose, a video sequence of the patient is firstly captured by using video camera and saved to system for further processing. The video frames are comprised of 640 by 480 pixels with RGB format. In proposed work, total 60 frames per second is recorded. After saving the frames of captured video, the image pre-processing is applied to the extracted frames of the video. The pre-processing is done to enhance the quality of the image. For this purpose, the median filter and adaptive histogram equalization is applied. The pre-processed frames are evaluated for measuring the mean of the frames. The FFT mechanism is applied for peak detection. Then on detected peak, the Butterworth filter i.e. band pass filters are applied. The band pass filters are applied to enhance the edges of the extracted frames. This section defines the flow of the proposed work along with its framework.

Step 1. Select Video:

The foremost step of the proposed work is to select the video of the patient from available set of videos. For this purpose, the video is captured by using the video camera and then stored to the system. The user has to select the video from available set of videos so that further processing could take place on it.

Step 2. Frame Extraction:

After capturing the video, the next step is to extract the frames from the captured video. Total 60 frames are extracted from the video. The video is the combination of scenes, the scenes are combination of shots and the shots are created by combining the frames. The key frames are extracted on the basis of the characteristics of the video.

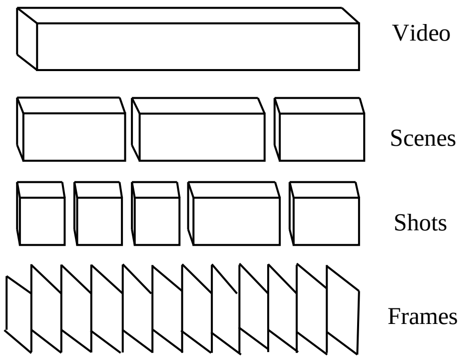


Figure 1 Video to Frame conversion process

In order to extort the features from the video, the separation of the frames is the major step. As after extracting the frames from video user can apply image enhancement techniques.

Step 3. Image Pre-Processing:

In this step, the image pre-processing techniques are applied to enhance quality and features of the image. Image pre-processing refers to the operating the image at lowest level. For processing the image, median filter and adaptive histogram equalization is applied.

i) Median Filter:

Median filter are non-linear filters that are specifically used to remove the noise from image so that the more informative content can be extorted properly without any flaws. Median filters are used to remove the salt and pepper noise. The working of median filter is similar to the working of mean filter as it follows the concept of moving window. In this, a 3*3, 5*5 or 7*7 kernel of pixels is scanned over the pixel matrix from whole frame or image. The median of the pixel value is evaluated and the centralized pixel of the window is replaced with the evaluated median value. As the median function generates the most robust output in contrast to the mean filters thus, the single very deceiving pixels in adjacent pixel will not impinge on median values extensively. While, the median value must be the value of adjacent pixel, the median filter does not generate new unrealistic value of the pixel. Therefore, the median filter is widely accepted since it preserves the sharp edges than other filters. The steps followed by median filter to improve the image quality are as follows:

---

a) A dimensional window of 3×3 is selected and centered around the processed pixels p(x,y) in the noisy image.
b) Sort the pixels in ascending order to the selected window size and evaluated median value of the sorted pixels defined by medium pixel by P_{med}, maximum pixel or last pixel by P_{max} and minimum or first pixel by P_{min} in the sorted vetor V_0.
c) If the processed pixel is within the range of $P_{min} < P(x,y) < P_{max}, P_{min} > 0 \; and \; P_{max} < 255,$ it is classified as uncorrupted pixel and it is unchanged. Otherwise p(x,y) is classified as noisy pixel.
d) If p(x,y) is a noisy pixel, then:
   - Case 1: If $P_{min} < P_{med} < P_{max} \; and \; 0 < P_{med} < 255 \; then \; p(x,y) = P_{med}$
   - If Case 1 in not satisfied then P_{med} is considered as noisy pixel. Pin this case evaluate the distance (V_D) within the each pair of the adjacent pixels of vector V_0. From V_D find out the maximum value and mark it to the corresponding value in V_0.
e) Repeat from step first to fourth until the whole image is processed.

---

ii) Adaptive Histogram Equalization (AHE) [9]

Adaptive histogram equalization mechanism is used to enhance the contrast in the image. AHE is suitable to the images that comprised of local regions either low contrast or dark regions. In AHE, only small regions are considered for processing on the basis of the local cdf of the particular region. The steps for AHE are as follows:

---

a) Evaluate the size of the grid on the basis of the maximum dimensions of the image whereas the minimum grid size is of 32 pixel square.
b) Select the grid size to the default window if the size of the window is not specified.
c) Classify the grid points in the image, by initiating from top-left corner of the image. The grids points in the image are differentiated by grid size pixels.
d) Evaluate the cdf of the region corresponding to the each grid point.
e) Repeat step 6 to 8 for each pixel in the image.
f) Locate 4 most adjacent grid points surrounding that specific pixel.
g) Find the mapping at selected 4 grid points on the basis of their index i.e. intensity value and cdfs.
h) Interpose among these evaluates values to find out the mapping at the current location of the pixel. Map the intensity to the range [min: max] and put it to the output image.

After applying median filter and AHE for image pre-processing, evaluate the mean value of the each frame.

Step 4. Peak Detection:

For peak detection, first of all, the three layers from RGB image is extracted. The formulation for RGB model is as follows:

First of all the RGB normalization is done to convert the image.

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B} \dots\dots (1)$$

After applying the RGB model, the HSI model is also applied to the extracted frames. The formulation for this is as follows:

Following normalized HSI component is observed:

$$h = \left\{\frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-g)(g-b)]^{1/2}}\right\} h \in [0,\pi] for\ b \le g \dots (2)$$

$$h = 2\pi - cos^{-1}\left\{\frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-g)(g-b)]^{1/2}}\right\} h \in [0,2\pi] for\ b > g \dots (3)$$

$$s = 1 - 3.min(r,g,b); s \in [0,1] \dots. (4)$$

$$i = \frac{R+G+B}{3.255}\ \ i \in [0,1] \dots\dots. (5)$$

Then, mean value of individual frame for all layers corresponding to both of the color model is evaluated. The R_m, G_m, B_m for RGB model and H_m, S_m, I_m for HSI model.

$$\frac{1}{n}\sum_{i=1}^{n} x_i \dots\dots (6)$$

x_i refers to the pixel value of the image

In this step the peak detection is done by applying the Fast Fourier Transform (FFT) function. Function of Fourier Transform can be described as an operation that would convert real variable function into another function. New type of functions is represented in frequency domain and this obtained function describes that which frequencies are represented in real function. Consequently, functions are disintegrated into the oscillatory function by using the Fourier Transform. FFT [10] is used in our work because frequency components are treated as important characteristic of an image. The domain of image is transformed to frequency by using FFT technique. The scale variation thus produced can make the process of extracting important features of image easier. Thus, FFT is an important step in image fusion technique that aims at identifying the more significant image features than the less significant ones. The function used for FFT evaluation is as follows:

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{k_x} . 0 \le K \le N-1 \dots. (7)$$

$$W_N - e^{-j2\pi 1N} \dots\dots (8)$$

$x(n)$ refers to the sequence of data with length N. The FFT is applied to each and every layer of both of the color model.

Step 5. Band Pass Filtration and optimization process:

In this step, the band pass Butterworth filters are applied to remove the electric noise, drift rates from the signals. It is firstly used by Stephen Butterworth. Basically, it was developed to have flat frequency response. The magnitude frequency response of Butterworth filters are evaluated as follows:

$$|H(\Omega)|^2 = \frac{1}{1+(\Omega/\Omega c)^{2N}} = \frac{1}{1+\epsilon^2(\Omega/\Omega p)^{2N}} \dots.. (9)$$

Where A depicts the filter gain, N is a filter order, Ωc defines the -3db frequency, Ωp is a pass band edge frequency and $\frac{1}{1+\epsilon^2}$ defines the band edge with the value of $|H(\Omega)|^2$. In this, the magnitude response reduces with the increment in the frequency. After applying the Butterworth band pass filter, next step is to evaluate the PSO optimization technique. The PSO [11] is a swarm intelligence based optimization technique. The idea of social foraging behavior of animals is the major base behind the working of PSO. It is comprised of collection of particles that budge around the given search space prejudiced by their own best past location. Corresponding to the each iteration, the particle velocity is upgraded by using the following formulation.

$$v_i(t+1) = v_i(t) + \left(c_1 \times rand() \times \left(p_i^{best} - p_i(t)\right)\right) + \left(c_2 \times and() \times \left(p_{gbest} - p_i(t)\right)\right) \dots.. (10)$$

Where, $v_i(t+1)$ depicts the new velocity value for i^{th} particle,

c_1, c_2 are the weight coefficient for local best and global best,

$p_i(t)$ defines the position for the i^{th} position for particle at time t,

p_i^{best} states the best known position for i^{th} particle,

The position of the particles is updated by using the following equation:

$$p_i(t+1) = p_i(t) + v_i(t) \dots. (11)$$

Step 6. Z Score evaluation: Basically, a z-score is the quantity of standard deviations from the mean a data point is. Logically, it is an estimation of how many standard deviations occurred above or below the population mean raw score is. A z-score is otherwise called a standard score and it tends to be put on a typical distribution curve. The expression for z score is illustrated below as:

$$z = \frac{x - x}{\sigma_x} \dots (12)$$

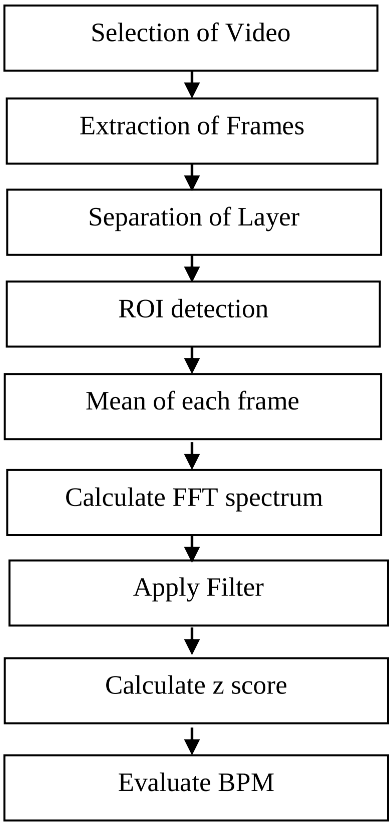


Figure 2 Block Diagram of the proposed work

IV. IMPLEMENTATION

This section represents the results that are obtained after implementing the proposed heart rate prediction mechanism in MATLAB. The classification of the observed results is done on the basis of the defined objectives.

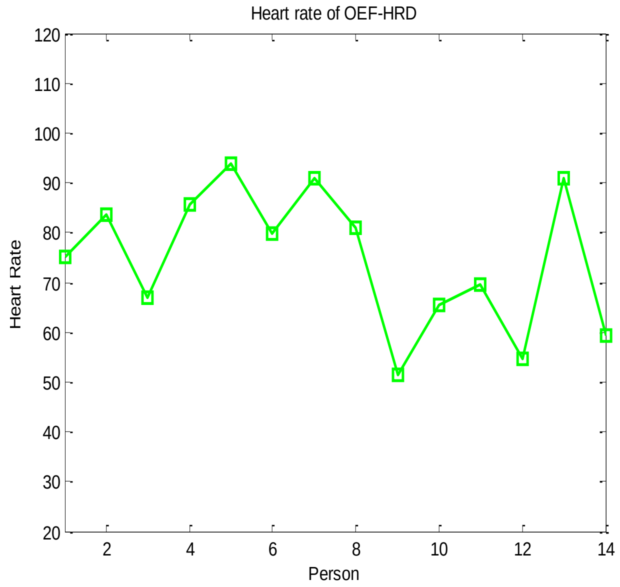
Table 1 Performance Analysis of proposed work after implementing enhancement process only (E-HRD)

Actual BPM	BPM RGB Layer	Overall Best BPM	Error rate	Z Score
75	75,45,45	75	0	-0.047
83.6	87,87,87	87	3.4	-0.043
68	60, 111,60	60	8	-0.047
86.06667	81,45, 111	81	5.066667	-0.048
96	48, 93,57	93	3	-0.050
80	48,69,75	75	5	-0.046
91	81,114,84	84	7	-0.048
81	48,48,84	84	3	-0.047
55	48,48,48	48	7	-0.046
59.6	45,48,123	48	11.6	-0.048
70	45,75,48	75	5	-0.047
55	48,48,48	48	7	-0.042
92	45,99,111	99	7	-0.048
58	45,45,48	48	10	-0.042

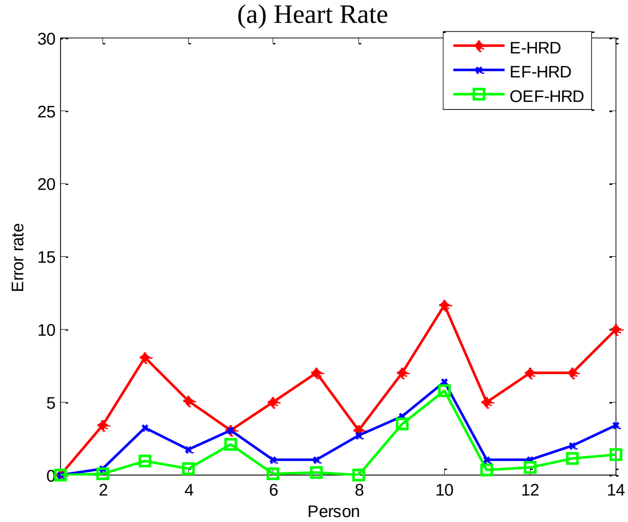
The overall performance of the proposed work for E-HRD is evaluated with respect to the videos of different 14 patients. The highest error rate of proposed work for E-HRD is 0 and the highest error rate is 11.6 for 10th video. The facts observed from the graphical performance of the proposed work for EF-HRD are calibrated in table 2. The table shows the value obtained corresponding to the actual BPM, BPM of R layer, G layer, B layer, H layer, S layer and I layer. Along with this the overall best BPM, Error Rate and Z score.

Table 2 Performance Analysis of Proposed after implementing color models (EF-HRD)

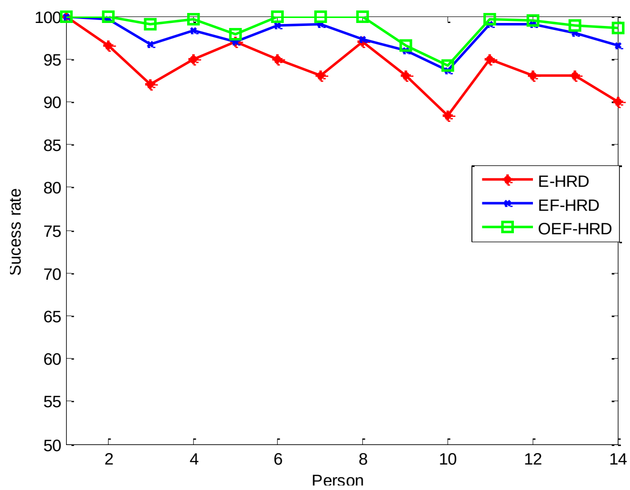
Actual BPM	BPM RGB Layer	BPM HSI Layer	Best BPM	Error rate	Z Score
75	75,96, 42	45,75,75	75	0	-0.019
83.6	120, 120,120	84,63,120	84	0.4	0.32
68	117, 114,114	108,64.7,117	64.77	3.22	-0.032
86.06	45,42,84.37	54,54,54	84.37	1.69	0.004
96	111,84,51	93,54,111	93	3	0.02
80	42,114,42	123,81.03, 42	81.03	1.03	0.04
91	69,54,54	90,75,69	90	1	0.03
81	120,114,111	83.7,108,120	83.7	2.7	0.11
55	69,75,51	102,42,69	51	4	-0.04
59.6	114,123,42	72,66,114	66	6.4	-0.03
70	93,72,60	105,69,90	69	1	-0.01
55	111,108,93	42,54,111	54	1	-0.01
92	120,90,111	111,42,81	90	2	-0.03
58	111,61.38,120	75,84,111	61.38	3.38	-0.02



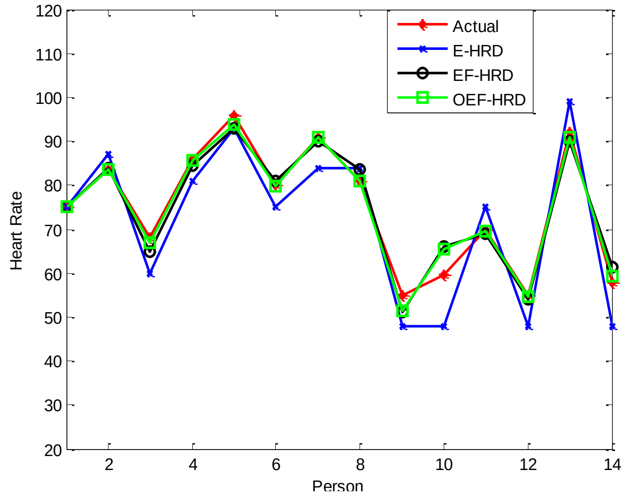
(a) Heart Rate



(b) Error Rate



(c) Success Rate



(d) Comparison Analysis

Figure 3 Performance Evaluation (a) Heart Rate (b) Error Rate (c) Success Rate (d) Comparison Analysis of Heart Rate of actual, E-HRD, EF-HRD and OEF-HRD of Proposed Work

Under this objective, the Particle Swarm Optimization (PSO) is applied to images or frames. This section defines the results that are obtained after applying the OEF-HRD to the output of the EF-HRD.

The performance of the proposed work is shown in the terms of heart rate, error rate and success rate and represented in the figure 3. Along with this the deep analysis are shown in table 3 in the terms of BPM, Z score, Error Rate and Success Rate.

Table 3 Performance Analysis of Proposed Work after implementing the optimization technique (OEF-HRD)

Actual BPM	**BPM RGB Layer**	**BPM HSI Layer**	**Over all Best BPM**	**Erro r rate**	**Z Score**
75	75,96,42	45,75,75	75	0	-0.01
83.6	120,120,120	83.58,63,120	83.58	0.02	0.32
68	117,114,114	108,67.05,117	67.05	0.94	-0.03
86.06	45,42,85.7	54,54,54	85.714	0.35	0.004
96	111,84,51	93.93,54,111	93.93	2.06	0.02
80	42,114,42	123,79.9,42	79.92	0.08	0.04
91	69,54,54	90.9,75,69	90.90	0.09	0.03
81	120,114,111	81,108,120	81	0	0.11
55	69,75,51.5	102,42,69	51.51	3.48	-0.04
59.6	114,123,42	72,65.3,114	65.34	5.74	-0.03

70	93,72,60	105,69.6,90	69.69	0.30	-0.01
55	111,108,93	42,54.5,111	54.54	0.45	-0.01
92	120,90.9,111	111,42,81	90.90	1.09	-0.03
58	111,59.4,120	75,84,111	59.4	1.4	-0.02

V. CONCLUSION

To overcome the issues such as complexity, cost and inconveniences in ECG machines a better method is proposed in this work. The major concern of the proposed work is to evaluate the heart rate based on the color variation in the video of the patient. The main parts contained in this new method are selection of video, extraction of frames, separation of layer, peak detection, median filter, z score evaluation, PSO mechanisms. The results of the proposed work are obtained on the basis of three objectives that are E-HRD, EF-HRD, OEF-HRD and also based on the comparison analysis. The heart rate obtained by implementing E-HRD is identical to the actual heart rate. After that the EF-HRD is implemented that is advanced video frames quality enhancement method it is demonstrated that the error rate is less and success rate is high comparative to the E-HRD. The value of heart rate of EF-HRD is closer to the values of the actual heart rate which means by utilizing image pre-processing techniques, color models and filtration schemes, the heart rate d detection can done more effectively with high accuracy rate. Now, OEF-HRD is implemented to resolve the problem of selection model for filter coefficients under which the Particle Swarm Optimization (PSO) is applied to images or frames. This objective offers better values of heart rate (error rate, success rate) comparative to the EF-HRD. Ultimately, Final comparison is done on the basis of correlation, success rate, Z score, BPM and error rate of the proposed and the existing method among the results obtained from the results of E-HRD, EF-HRD, and OEF-HRD respectively. Hence, it is proved from the results that the proposed work is effective and reliable to detecting heart rate from video of patients. As the proposed work offers better results but more amendments are also possible in this work. Likewise the heart rate in the proposed work is obtained by using face recognition but it can be evaluated by using different regions of interest that are cheeks, forehead etc.

REFERENCES

[1]. Qibin Zhao, and Liqing Zhan, "ECG Feature Extraction and Classification Using Wavelet Transform and Support Vector Machines," International Conference on Neural Networks and Brain, ICNN&B '05, vol. 2, pp. 1089-1092, 2005.

[2]. B. Castro, D. Kogan, and A. B. Geva, "ECG feature extraction using optimal mother wavelet," The 21st IEEE Convention of the Electrical and Electronic Engineers in Israel, pp. 346-350, 2000.

[3]. S. Z. Mahmoodabadi, A. Ahmadian, and M. D. Abolhasani, "ECG Feature Extraction using Daubechies Wavelets," Proceedings of the fifth IASTED International conference on Visualization, Imaging and Image Processing, pp. 343-348, 2005.

[4]. Vasu Jindal, "Mobile SOFT: U: A Deep Learning Framework to Monitor Heart Rate During Intensive Physical Exercise", ACM

[5]. Feng Xiao, Ming Yuchi, Jun Jo, Ming-yue Ding, Wen-guang Hou, "A Research of Physical Activity's Influence on Heart Rate Using Feedforward Neural Network", Springer, International Symposium on Neural Networks, 2009

[6]. Stephen Roy, Jean Mccrory, "Original Research Validation of Maximal Heart Rate Prediction Equations Based on Sex and Physical Activity Status", International Journal of Exercise Science, Vol 8(1), Pp 318-330, 2015

[7]. Ming Yuchi, Jun Jo, "Heart Rate Prediction on Physical Activity using Feedforward Neural Network", International Conference on convergence and hybrid information technology, Pp 344-350, 2008

[8]. Melanie Ludwig, Harald G. Grohganz and Alexander Asteroth, "A Convolution Model for Heart Rate Prediction in Physical Exercise", 4th International Congress on Sport Sciences Research and Technology Support, Pp 157-164, 2016

[9]. http://www.cs.utah.edu/~sujin/courses/reports/cs6640/project2/ahe.html

[10]. http://www.cmlab.csie.ntu.edu.tw/cml/dsp/training/coding/transform/fft.html

[11]. http://www.cleveralgorithms.com/nature-inspired/swarm/pso.html

[12]. Aibek Ryskaliyev, Sanzhar Askaruly, lex Pappachen James, "Speech Signal Analysis for the Estimation of Heart Rates Under Different Emotional States", IEEE, Advances in Computing, Communications and Informatics (ICACCI), 2016.

[13]. Xiao, Feng, Chen, Yi-min, Yuchi, Ming, Ding, Ming-yue, Jo, Jun Hyung, "Heart Rate Prediction Model based on Physical Activities using Evolutionary Neural Network", IEEE, Pp 198-201, 2010.

[14]. Andreas Tsiartas, Andreas Kathol, Elizabeth Shriberg, Massimiliano de Zambotti, Adrian Willoughby, "Prediction of Heart Rate Changes from Speech Features During Interaction with a Misbehaving Dialog System", ISCA, Pp 3715-3719, 2015

[15]. Ming-Zher Poh , Daniel J. McDuff , Rosalind W. Picard, "Advancements in Noncontact, Multiparameter Physiological Measurements Using a Webcam", IEEE, Transactions on Biomedical Engineering, Vol 58 (1), 2011

[16]. Sudhakar Mishra, Uma Shanker Tiwary, "Heart Rate Measurement Using Video in Different User States for Online HCI Applications", ELSEVIER, Vol 39, Pp 20-27, 2014

[17]. Xiaobai Li, Jie Chen, Guoying Zhao, Matti Pietik¨ainen ,"Remote Heart Rate Measurement From Face Videos Under Realistic Situations", IEEE, Pp 4321-4328, 2014
[18]. Afseen Naaz, Shikha Singh, "Feature Extraction and Analysis of ECG signal for Cardiac Abnormalities- A Review", International journal of Engineering Research and Technology, Vol 3 (11), 2014
[19]. H. Hermansky, N. H. Morgan, and P. D. Kohn, "Auditory model for parametrization of speech," Sep. 12 1995, uS Patent 5,450,522.
[20]. H. Hermansky, N. Morgan, A. Bayya, and P. Kohn, "Rasta-plp speech analysis technique," in icassp. IEEE, 1992, pp. 121–124.
[21]. N. A. Meseguer, "Speech analysis for automatic speech recognition," Norwegian University of Science and Technology, Masters Thesis, vol.109, 2009.
[22]. Kuo-Kuang Jen, and Yean-Ren Hwang, "ECG Feature Extraction and Classification Using Cepstrum and Neural Networks," Journal of Medical and Biological Engineering, vol. 28, no. 1, 2008.
[23]. V. S. Chouhan, and S. S. Mehta, "Detection of QRS Complexes in 12- lead ECG using Adaptive Quantized Threshold," IJCSNS International Journal of Computer Science and Network Security, vol. 8, no. 1, 2008.
[24]. Xiaomin Xu, and Ying Liu, "ECG QRS Complex Detection Using Slope Vector Waveform (SVW) Algorithm," Proceedings of the 26th Annual International Conference of the IEEE EMBS, pp. 3597-3600, 2004.
[25]. C. Alexakis, H. O. Nyongesa, R. Saatchi, N. D. Harris, C. Davies, C.Emery, R. H. Ireland, and S. R. Heller, "Feature Extraction and Classification of Electrocardiogram (ECG) Signals Related to Hypoglycaemia," Conference on computers in Cardiology, pp. 537-540, IEEE, 2003.
[26]. Alan Jovic, and Nikola Bogunovic, "Feature Extraction for ECG Time- Series Mining based on Chaos Theory," Proceedings of 29th International Conference on Information Technology Interfaces, 2007.