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An Approach in Monitoring and Tracking Heart Rate from Video one of the Future Biomedical Research

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Abstract: A unique model is proposed in this paper through which the heart rate of the patient is evaluated by analyzing the color variations in the patient's video that is by far considered as the most accurate and precise method for detecting heart rates.For this, a video stream is collected by using the webcam which is later stored in the system for subsequent analysis with a frame rate of 60 frames/sec. After this, video frames are extracted and preprocessing is performed on it, so that the quality of image is enhanced. Once this is done, the next step is to calculate the mean of these processed frames which is done by using Adaptive histogram equalization and a median filter. Moreover, the to detect the peak in the proposed work FFT approach that employs Butterworth Filter is used for enhancing the edges of exorted frames.The effectiveness of the suggested work is carried out and analyzed in MATLAB simulation software. The simulation results were obtained in terms of various performance dependency factors, which showed the supremacy of the proposed framework in E-HRD, EF-HRD and OEF-HRD systems respectively.

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

Keywords: Groundwater quality, Physiochemical analysis, Water pollution, Water Quality Index, Water analysis.

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1. Introduction

Electrocardiogram oftenly known as ECG is a biomedical equipment that is used to determine a variety of cardiac processes and functions. ECG gives a plethora of information about the heart's basic or specialized anatomy[1]. The Electrocardiograph impulses have a wide range of distinct characteristics which makes diagnosing and evaluating ECG a difficult operation. As a result, using computer-based approaches to analyze the ECG data is quite necessary. Moreover, the assessment and quantification of outputs is a complicated job because of the significant variations and unpredictability of ECG signals [2-5]. The fluctuations that occur in the ECG signal are non-periodic that do not occur at previously determined time intervals. Also, the visual based tests are not always accurate. As a result, the demand for using the computer-based approaches for examining the ECG signals increased [6]. The electric impulses are generated by the contraction and relaxation of cardiac muscles that are then assessed by the device's functioning through the skin [7]. This technique is employed for detecting the rate and the frequency at which the heart is beating in order to identify any irregularity in the heart with minimum effort [7]. Hence, in other words, the ECG can be described as the equipment that is used to display the heart activity in the form electrical impulses on the screen [8].

2. Methodology

In the suggested scheme, the patient’s heart rate is determined by examining the color variability in video stream. In order to achieve the proposed objective, a video stream of patient is obtained initially via camera. This video stream is then stored in the system for further processing. the video sequence obtained is in the RGB format with a resolution of 640 by 480 pixels.A maximum of 60 frames per second are captured in the proposed method. Once the video frames are attained from the given video sequence, image pre-processing is applied to it. The main objective to perform pre-processing is to enhance the quality of image. In the proposed method, pre-processing is done using the median filter and adaptive histogram equalization. Once these frames are normalized, these are analyzed for determining the frame mean value. In addition to this, the authors have also applied FFT approach for peak detection. After detecting the peak, the Butterworth filter also known as band pass filter is applied in order to improve the edges of the frames obtained from the video sequence. The detailed working of the proposed method is described in this section.

2.1 Video selection

The first and foremost step that is opted in the suggested scheme is to elect video sequence from the accessible videos. Here, a video camera is used that captures the video of the patients and save it in the system for subsequent processing.

2.2 Frame extraction

Once the video stream is obtained from the video camera, the next phase is to pull out frames from it. Basically, a video sequence is a group of scenes which in turn is a combination of various shots. These shots are formed by mixing a number of frames together to form a video. In the proposed work, a total of 60 frames second is obtained from the video. The process of frame conversion is shown in Fig. 1 below,

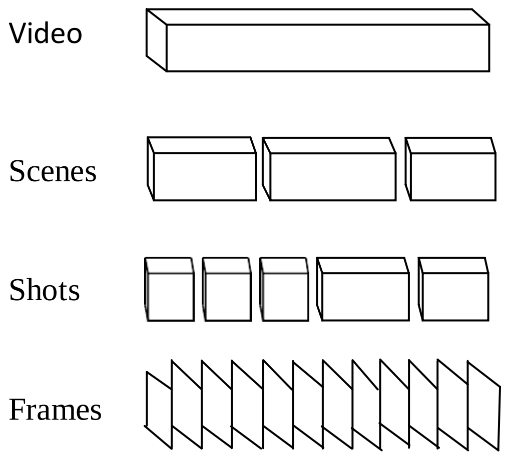

Fig. 1 Conversion procedure in video

The segregation of the frames from the given video sequence is a crucial step in extracting features from it. Following the extraction process, an image enhancement methodology is applied that helps to improve the quality of images.

2.3 Image pre-processing

Once the frames are obtained from the available video stream, the next step is to apply image pre-processing on these frames for enhancing its quality and characteristics. Here, we have utilized median filter and adaptive histogram equalization technique for pre-processing images. The main motive of using these techniques is described below;

2.4 Median Filter

It can be defined as the type of filter that is utilized to eliminate noise from images in order to extract only useful content from the images. In addition to this, the median filter is also capable of reducing the salt and pepper noise from the images. since, it adopts the concept of moving window, the working mechanism of the median filter is quite familiar with that of the mean filters. A 3×3, 5×5, or 7×7 pixel kernel is examined with respect to pixels from the entire picture in this technique. The centralized window pixel is then substituted by the calculated median value of pixels. Because the median function in contradiction to the mean filters, produces the much more regulated output. Therefore, a single deceptive pixel in a neighbouring pixel will not have a significant impact on median values. The median filter does not spawn new unrealistic pixel values, despite the fact that the median value should be the outcome of a nearby pixel. As a result, the median filter is extensively used because it retains sharp corners better than other available filters. The actions taken by the median filter to enhance quality of image are listed below.

- Initially, a window is selected whose dimensions are 3×3, which is centred near the normalized pixels p (x, y) in noisy images.
- After this, pixels are sorted in the ascending order with that of chosen window size. After this, the median of these sorted pixels is calculated in the sorted vector V_o which is determined by the medium pixel by P_{med}, the maximum pixel i.e. P_{max}, and the minimum or first pixel by P_{min}.
- If the value of processed pixel lies in the range of $Pmin < (x, y) < P$, $Pmin > 0$ *and* $Pmax < 255$, then it is categorized as uncorrupted pixel, else, p(x,y), is considered as the noisy pixel.
- When p(x,y) is a noisy pixel, then:
- Scenario 1: If $Pmin < Pmed < Pmax$ *and* $0 < Pmed < 255$ *then* $p(x, y) = Pmed$

  Otherwise, $Pmed$ is taken as noisy pixel. This value is saved and the distance i.e. V_D in every pair of neighbouring pixels, represented by Vo. After this, the value of V_o is used for calculating the largest value of neighbouring pixels V_o
- This process is repeated from step first to fourth until.

2.5 Adaptive Histogram Equalization (AHE)

To improve the brightness in the picture, an adaptive histogram equalization process is applied [9]. AHE is appropriate for photos with poor contrast or dark local locations. Usually tiny portions are evaluated for processed in AHE, and this is based on local cdf of the location. The following are the steps for AHE:

- Determine the size of the grid based on the picture's highest proportions, with a minimum 32-pixel square grid size.
- If somehow the size of window is not given, the size of the grid is selected based on the default size of window.
- Starting at the top-left corner of the picture, categorize the grid points in the picture. Grid size pixels and the grid points of the image are totally different.
- Calculate the cdf for the area that corresponds to every grid point.
- For every pixel of an image, repeat steps 6–8.
- Calculate the cdf for the area that corresponds to every grid point.
- For every pixel of an image, repeat steps 6–8.
- Evaluate the four grid points that are closest to that pixel.
- Using their indices, i.e. intensity score and cdfs, determine the mapping at four grid points.
- Determine the mapping at the present pixel location by interposing these evaluates values. Set the brightness on the output image and map it to the range [min: max].

Once the images are processed by the median filter and AHE, it is time to calculate the mean value for every frame available.

3. Peak detection

In order to detect the peak value of the images, it is important to extract the EGB layers from the image. The RGB model can be evaluated by the formulation given in this section;

Initially, the RGB images are normalized for converting the image by the formula given below,

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

The HSI model is implemented to the retrieved frames just after the implementation of RGB model. The following is the formula for this:

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

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

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

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

After this, the mean in every frame in all layers is calculated for both color models. The RGB model uses R_m, G_m, B_m, while the HSI model uses H_m, S_m, I_m respectively.

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

Where, x_i represents the pixel value of the image.

Once the mean value of all the individual frames is calculated, the next step is to determine the peaks values, which is done in the proposed work by applying fast Fourier transformer (FFT).The Fourier Transform function can be defined as a procedure in which a real valued function is converted into another function which are demonstrated in the frequency domain. These functions give enough information about every frequency shown in the real function. As a result, the Fourier Transform is used to decompose functions into the oscillatory function [10]. Using the FFT method, the image's domain is converted to frequencies. The resulting scale fluctuation may make the task of retrieving crucial features of an image simpler. As a result, FFT is a crucial stage in the image fusion approach, which tries to find the more relevant image elements over the less critical items. The formula for computing FFT is given as;

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{k_x} . 0 \leq K \leq N-1 \quad W_N - e^{-j2\pi 1N} \quad (7)$$

Where, (n) represents the sequence of data with length N.

4. Band pass filtration and Optimization process

The next step that is followed by the proposed method is to apply filtration process. For this, Butterworth filter has been used so that it can effectively eliminate the noise and drift rates from the signals. Stephen Butterworth is the first to use

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it.It was created with the goal of getting a flat frequency response that can be assessed as:

$$|H\ (\Omega)|^2 = \frac{1}{1+\left(\frac{\Omega}{\Omega c}\right)^{2N}} = \frac{1}{1+\epsilon^2\left(\frac{\Omega}{\Omega p}\right)^{2N}} \quad (8)$$

Where A and N represents the filter gain and filter order respectively, Ωcexplains the frequency with values equal to -3db, Ωp represents the frequency of pass band edge and $1/1+\epsilon^2$ represents the band edge whose value is set with $|H\ (\Omega)|^2$. In such cases, the MR (magnitude response) starts to decrease, as soon as the frequency starts to increase. Once the Butterworth filter is applied, it is now time to implement the PSO optimization method. The PSO [11] is an intelligent population based meta-heuristic optimization algorithm. It is made up of a group of particles which move throughout a particular search space, guided by their finest previous location. The particle velocity is modified for each repetition by applying the following formula.

$$v_i(t+1) = v_i(t) + (c_1 \times rand\ () \times \left(p_i^{best} - p_i(t)\right) + (c_2 \times and\ () \times \left(p_{gbest} - p_i\ (t)\right) \quad (9)$$

Where, $vi\ (t+1)$ represents the updated velocity for i^{th} particle, $c1$, $c2$ represent the local best and global best weight coefficients, $pi(t)$ represents the location for the i^{th} position of particle at time t, $pibest$ depicts the best-known location for i^{th} particle. The location of the particles is evaluated by the formula given below,

$$p_1(t+1) = p_i(t) + v_i\ (t) \quad (10)$$

5. Z-score calculation

A z-score can be typically defined as the number of standard deviations, a data point deviates from the mean. In other words, it can also be defined as the calculation which determines total number of standard deviations that occurred up or down population mean raw score. The z-score can be evaluated by the expression given below;

$$z = \frac{x-x}{\sigma_x} \quad (11)$$

The flow chart of the proposed model is given in Fig. 2;

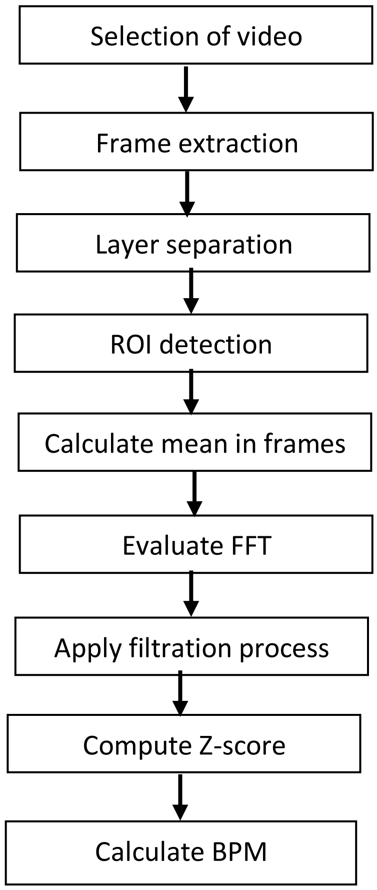

Fig. 2 Proposed system framework

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6. Performance Analysis

In this section, the effectiveness of the proposed heart rate prediction system is validated and analyzed in the MATLAB software. The results are classified in terms of various performance metrics for three color models, those are, E-HRD, EF-HRD and OEF-HRD.

Initially, the performance of the proposed heart rate detection model is validated for the E-HRD color model using videos from 14 distinct patients. The maximum error rate for E-HRD model came out to be 0 and the maximum error rate for the 10th video is 11.6. Similarly, the performance of the proposed hart rate prediction model is also evaluated for the EF-HRD color model. The results were obtained in terms of actual BPM, BPM for R, G, B, S and I layers respectively. Moreover, the performance was also analyzed in terms of error rate and z score. After analyzing the results, maximum error rate is obtained for the 14th video which is equal to 3.38, while as the minimum error rate came out to be 0 for first video with actual BPM 75.

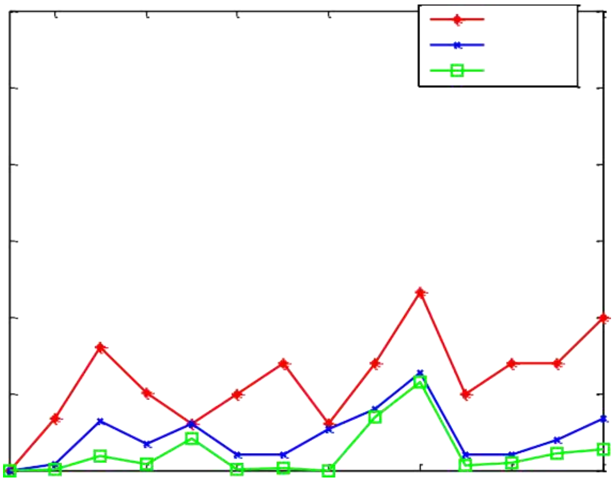

Fig. 3 Comparison for Error rate obtained

Furthermore, the performance of the proposed heart rate prediction model with PSO optimization is analyzed as per its heart rate, error rate and success rate. The comparison graphs obtained for the same process are shown in Fig. 3 and 4 respectively.

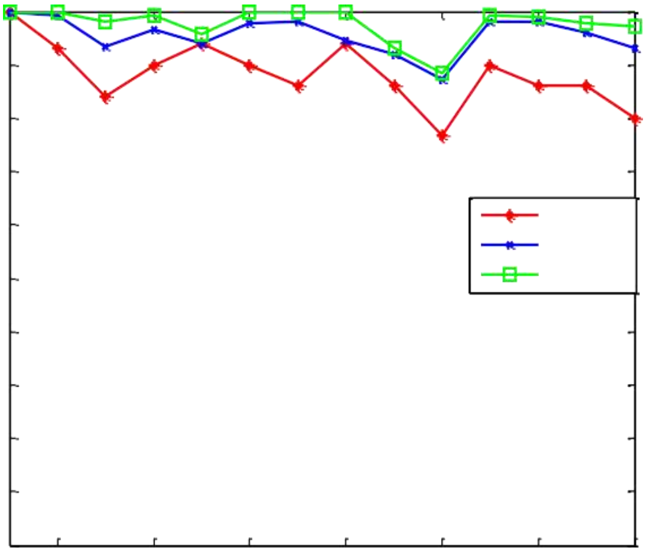

Fig.4 Comparison for Success rate

Fig. 3 and 4 represents the comparison graph for the proposed ORF-HRD color model in terms of Error rate and success rate.

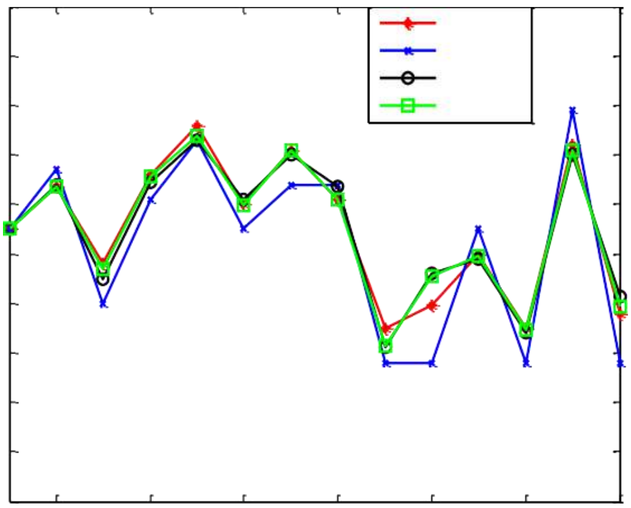

Fig. 5 Comparison for Heart rate

The red and blue lines depict the performance of E-HRD and EF-HRD models while as the green colored lines represent the performance of OEF-HRD model.

After analyzing the graphs, it is found that the suggested OEF-HRD approach is able to generate optimum results when compared with the remaining two models. Additionally, the performance of the suggested OEF-HRD model is also analyzed and compared with other two models in terms of heart rate. The graph obtained for the same is given in figure 5. The red line in the graph depicts the actual heart rate while as the blue, black and green depict the performance of the proposed E-HRD, EF-HRD and OEF-HRD models in terms of its ability to predict the heart rate. From the graphs, it is found that all the three models are showing good results andare very close to the actual BPM value.

However, out of the three models, the OEF-HRD model is showing the best results is has almost overlapped the actual BPM line as shown in the graph. The values obtained in the proposed OEF-HRD model in terms of error rate, z-score and other parameters are recorded in tabular form and are shown in the Table 1. After analyzing the values given in Table 1, it is observed that the maximum error rate in proposed ORF-HRD model came out to be 5.74 for 10th video while as the minimum error rate came out to be zero for first and 8th video respectively.

Table 1: Performance Analysis in Proposed OEF-HRD Model

Real BPM	**BPMR GB**	**BPM HIS**	**Best BPM**	**Error rate**	**Z-Score**
75	75,96,4	45,75,7	75	0	-0.01
83.6	120,120,12	83.58,63,12	83.58	0.02	0.32
68	117,114,11	108,67.05 11	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

7. CONCLUSION

An improved solution is provided in this research to tackle obstacles like intricacy, price, and annoyance in ECG devices. The suggested work's aim was to identify the person's heart rate by examining the color variations in the video stream. The suggested work's outcomes are composed of three goals: E-HRD, EF-HRD, and OEF-HRD, as well as a comparative assessment. The heart rate recorded through the use of E-HRD is the same as the true heart rate. Afterwards, the performance of the EF-HRD model is analyzed and it is shown that it has a lower error rate and a higher success rate than the E-HRD. In this case, the heart rate of the EF-HRD model came out to be much closer to the actual heart rate, which implies that the heart rate detection can be done more effectively and accurately using picture pre-processing methods, color models, and filtration systems. Finally, the performance of the proposed OEF-HRD model is used to tackle the challenge of selecting a filter coefficient selection model while using PSO algorithm. Furthermore, when the efficacy of the suggested OEF-HRD model is analyzed and contrasted with the prior E-HRD and EF-HRD models, it is found that the OEF-HRD model provides much better error rates and success rates. As a result of the findings, it is concluded that the suggested method for determining heart rate using video of individuals is both efficient and accurate. The proposed method produces better performance, but it also allows for additional modifications. Similarly, the heart rate in the suggested study is determined through face identification, but it can still be assessed through several ROI(regions of interest) such as the cheeks and forehead.

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