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ECG Analysis for HRV Detection

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Abstract: In this paper an algorithm is proposed for estimation of HRV with better accuracy and results. We are making use of Auto Regressive Model (AR Model) for the estimation. Since ECG wave is also contaminated with a lot of noise such as Power Line Interference (PLI), EMG and just some common artifacts like breathing disturbance's, so to filter out all this noise from the wave we are using Cumulant based AR model for filtering the wave. Using IoT we will later use real time ECG waves to estimate HRV.

Keywords: ECG, HRV, AR Model,

Cumulants

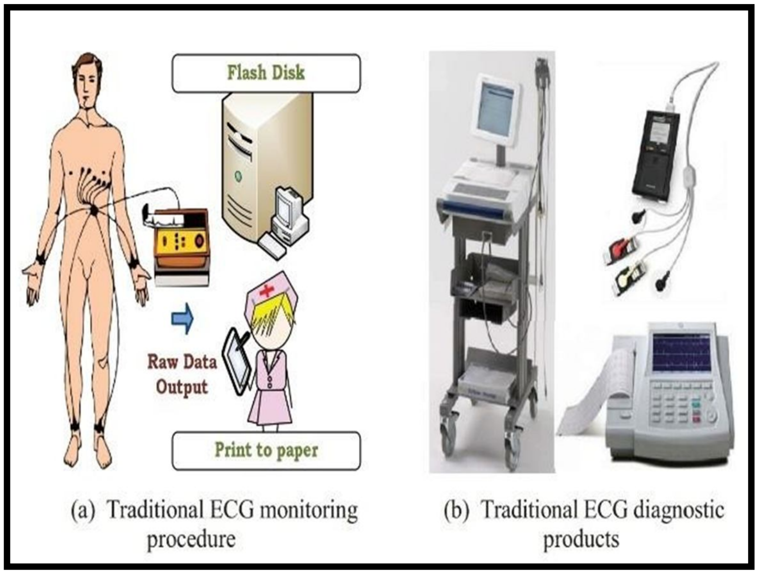

Figure 1: Traditional ECG monitoring procedure and products

I. INTRODUCTION

ECG signals tell us a lot about the patient's health and thus using this wave we will estimate HRV which is also very crucial to understand a lot of thing s about the subjects body such as the response of his/her nervous system. Since HRV is a result of fluctuation between the adjacent heart beats. So our project is based on the same concept of estimating HRV of a person. So in our paper we will be making use of the Cumulant's based AR model for enhancing the ECG signal[1] and that will be followed by QRS detection using an Main detector In which we have to set a Baseline Threshold and Detection Threshold in order to determine the QRS peaks and not any false positives after which the signal is passed through a Secondary detector which makes use of the Energy Signal to detect the complex[2]. The analysis will be done in the frequency domain and thus the parameters such as Very Low Frequency (VLF), Low Frequency (LF), High Frequency (HF) and the ratio of low frequency to high frequency (LF/HF) will be calculated using the parametric method of AR model. Since the conventional FFT non parametric method was not efficient because the signal with low amplitude was being masked and hence the results were not as expected and accurate.Also, using IoT we will be recording real time data and then storing and performing the analysis for real time application[4].

III. CUMULANTS

Since ECG wave is a non-minimum phase signal and contains a lot of noise so cumulants can be used for a better filtering of the wave. Cumulants are a combination of moments in a non linear manner. This method Is used in Higher Order Statistics. 1^{st} order cumulant gives the mean of the moment. 2^{nd} order gives the Variance, 3^{rd} order gives the skewness and 4^{th} gives the kurtosis.

The cumulant can be defined as :

$$c_1 = cum(x_1) = y_1 \quad (1)$$

This is 1st order cumulant and y_1 is the 1st moment.

$$c_2 = cum(x_1, x_1) = y_2 - y_1 \quad (2)$$

This is 2nd order cumulant and y_2 is the 2nd moment.

$$c_3 = cum(x_1, x_1, x_1) = y_3 - 3y_2y_1 - 2y_1^3 \quad (3)$$

This is 3rd order cumulant and y_3 is the 3rd moment.

Using this the coefficients of the AR model will be computed and then used as an filter to enhance the ECG wave.

IV. AUTOREGRESSIVE MODEL

AR model is a method in which the output of the given system is predicted based upon the previous output. The reason for selecting the parametric based AR model is because in the conventional non-parametric based method the frequency resolution was not as expected and also the problem of leakage i.e some signals with an low amplitude were being masked and this gave rise to problem with regarding the accuracy of the output while computing parameters. AR models have a form of :

$$[k] = \sum_{i=0}^{p+1} a_k v(k - i + 1) + w(n) \quad (4)$$

Where v[k] is the ECG wave w(n) is the white Gaussian noise with zero mean, a_k is the AR coefficient and p is the order of the AR model. ECG data is modeled by calculating the desired AR coefficients from the 3rd order cumulant rather directly calculating the AR coefficients from ECG.

$$y(n) = \sum_{i=1}^{p} a_k^{(2\pi i f_k + \theta_k)} + w(n)$$
$$= x(n) + w(n)$$

.

Where w(n) is additive noise, a_k is the amplitudes, f_k is the frequencies and θ_k is the phase.

V. QRS DETECTION

After the wave has been enhanced it is given as an input to the Main Detector as proposed in a paper that we referred[2].The concept used is that if the input signal crosses a certain threshold voltage which will be set then the event can be called as a QRS complex.
Where as if the event has more than 4 peaks then the event is classified as noise.
If the number of peaks are between 2 and 4 then the event is classified as QRS complex.
Two thresholds will be set namely Baseline Threshold and Detection Threshold. Detection Threshold will be used for comparison and Baseline will only serve the purpose of DT settings after the event is detected.

VII. FREQUENCY DOMAIN PARAMETERS

When it comes to frequency domain parameters there are some standard parameter that have been set namely ULF, VLF, LF and HF.

A. Ultra-low Frequency Band (≤0.003Hz). Period of24h.
B. Very-Low Frequency (0.0033- 0.04Hz) . Period of 5min but best 24h.
C. Low Frequency Band(0.04- 0.15Hz). Period of 2min minimum.
D. High Frequency (0.15- 0.40Hz). Period of minimum 1min.
E. LF/HF ratio which is based on 24h recording. Since PNS and SNS both contribute to the LF power and PNS activity contributes to HF power. The ration tells about the activity between SNS and PNS.

VIII. PROPOSED MODEL

I n this project we are working on making a small compact device that can be used in this novel of corona virus . The basic idea is to collect real time ECG data and store it in an online cloud using IoT or if there is no availability of Wifi then use an SD card to store it and use it for analysis in a later time. After the storage we intend of using the Cumulants based AR model to enhance the wave and then detect QRS complex to estimate HRV and compare parameters based on frequency domain using the parametric method based AR model again since it provides with a much better frequency resolution and accuracy.

IX. CONCLUSION

So, as described in the paper we plan on making a compact device to collect the ECG waves and perform the analysis to determine the HRV. So better filtering of the wave will help in executing the algorithms with a better accuracy and precision.

X. FUTURE SCOPE

Since the ECG wave tells us a lot about the human heart, this project can be used to monitor the same heath issues faced by people without having to go to hospitals and expensive facilities, since it can be used anywhere. HRV also helps athletes in training and understanding there recovery rate and can be helped to plan there training session In a much efficient manner. Real time collection of data can be implemented in first aid boxes since it is a compact device.

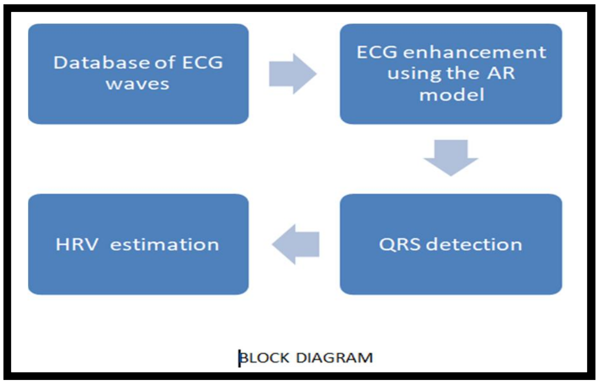

Figure 2: Block Diagram.

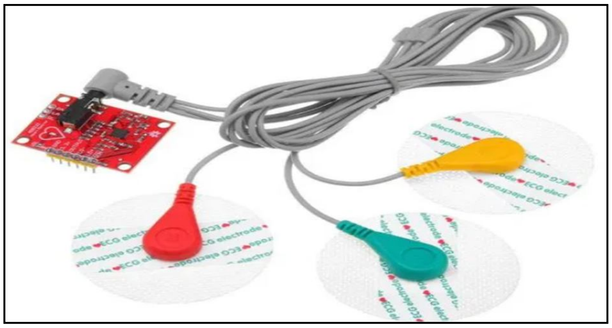

Figure 3: AD8232 Sensor and Electrodes

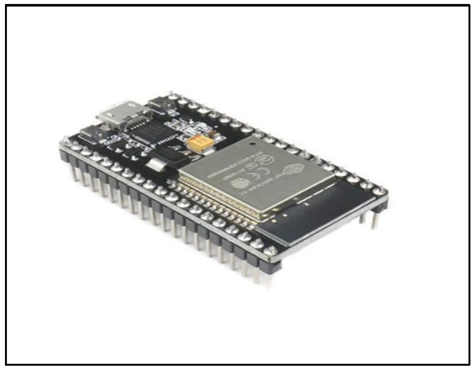

Figure 4: ESP32 Module

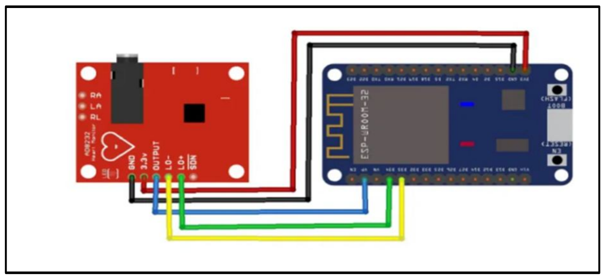

Figure 5: Circuit Diagram

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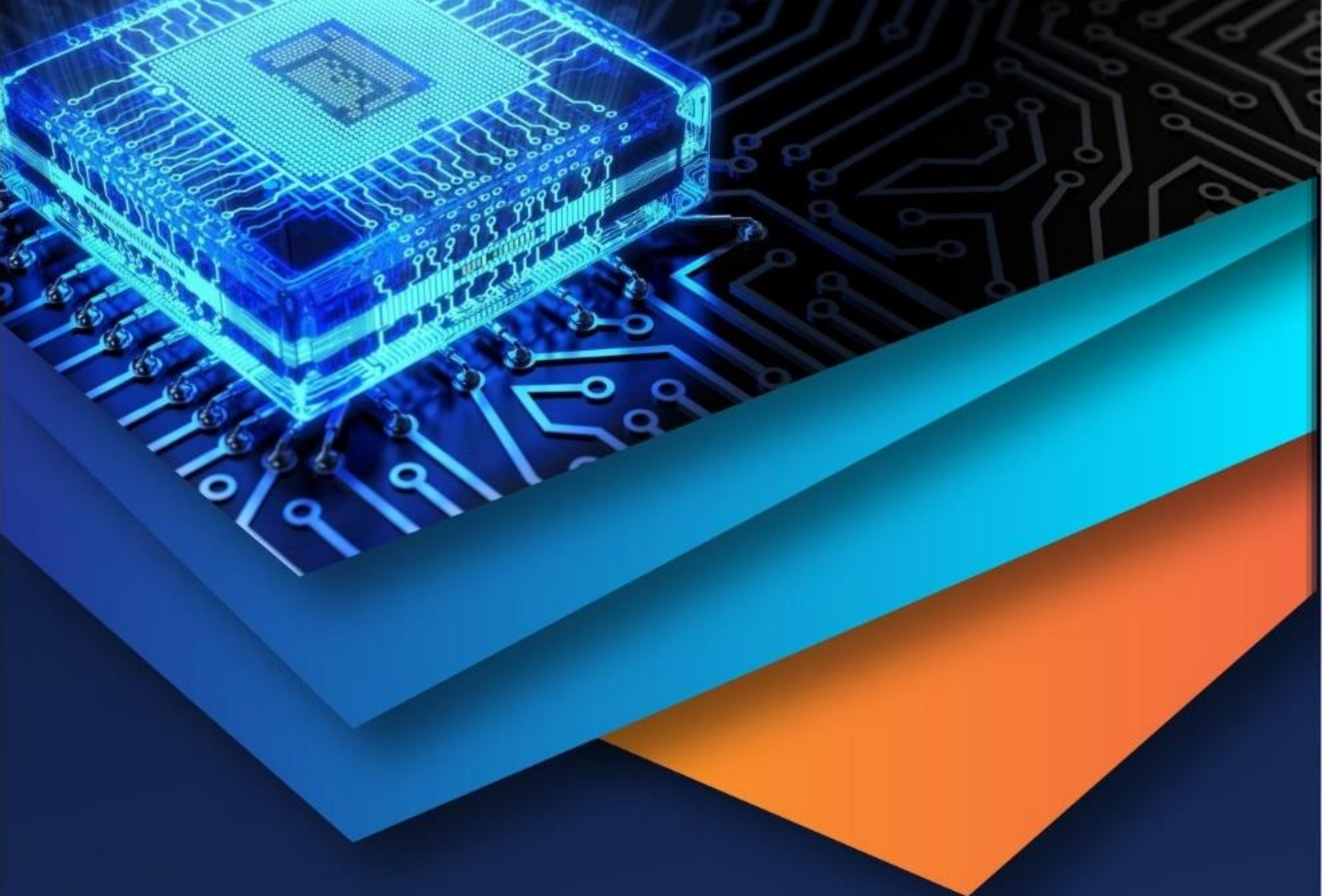

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