Doctor friendly software for HRV Analysis

N.D.Thakur, M.S.Sankhe, Dr.K.D.Desai

Abstract- **This paper discusses about the development of HRV analysis software using VB and MATLAB easy to be used and understand by the doctors. The developed software provides user friendly GUI which provides the doctors with HRV display along with time domain and frequency domain parameters calculated from HRV. The system provides time domain measures like heart rate in BPM for every minute of recording, average heart rate over the recording period of 5 minutes, mean NN interval, variance in NN intervals and SDNN. The system also provides frequency domain measures based on short term spectral analysis like total power (0.00 to 0.4 Hz), LF (0.00 to 0.04 Hz), MF (0.04 to 0.15 Hz) and HF (0.15 to 0.40 Hz) power in ms^2. The peak power in each frequency band along with the corresponding frequency is also indicated. To minimize the effect of total power fluctuations the MF and HF are also calculated in normalized units. The sympatho vagal balance (MF/HF) which indicates the influence of two branches of autonomic nervous system on HRV is also indicated for each patient samples. All the above the parameters provides the doctor an insight in to the state of the heart of the patient.**

Index Terms— **ANS, BPM, ECG, HRV, HRVPS, SDNN.**

I. INTRODUCTION

The variation in the time period separating consecutive heartbeats has come to be conventionally described as heart rate variability (HRV). These inter-beat intervals can be measured conveniently as the time separation between the R peaks of adjacent QRS complexes in a continuous electrocardiogram (ECG) recording. The sympathetic and parasympathetic branches of the autonomic nervous system (ANS) regulate the activity of the sinoatrial node, the cardiac pacemaker [1]. The beat-to-beat variation in heart rate therefore reflects the time varying influence of the ANS and its components, on cardiac function.

Over the last 25 years, HRV analysis has established itself as a non-invasive research and clinical tool for indirectly investigating both cardiac and autonomic system function in both health and disease [2]. The current methodologies used to analyse HRV are based largely on linear techniques to analyse 'past' and 'present' electrocardiogram data in time and frequency domains. For conventional time domain analysis, the variability in the R-R interval time series derived from an ECG recording is statistically summarised using conveniently calculated measures such as SDNN (standard deviation of time interval between consecutive R peaks resulting from sinus node depolarisation) and RMSSD (root-mean square of the difference between two adjacent R-R intervals)[2],[3]. Depending on the length of the analysed ECG recording, which may vary from a few minutes to 24 hours, and the choice of the time domain measure, both short-term and long-term HRV can be quantified and characterised. While time domain measures help in assessing the magnitude of the temporal variations in the autonomically modulated cardiac rhythm, the frequency domain analysis provides the spectral composition of these variations [4], [5]. The underlying assumption behind the traditional frequency domain HRV analysis is the 'time invariance' or 'stationarity' of the signal, i.e., the individual spectral components do not change over the duration of signal acquisition. Through the use of computationally efficient algorithms such as Fast-Fourier Transform (FFT), the HRV signal is decomposed into its individual spectral components and their intensities, using Power Spectral Density (PSD) analysis. These spectral components are then grouped into three distinct bands [2], [4], [5]: low frequency (LF), mid frequency (MF) and high frequency (HF). The cumulative spectral power in the MF and HF bands and the ratio of these spectral powers (MF/HF) has demonstrable physiological relevance in healthy and disease states. Changes in the MF band spectral power (0.04– 0.15Hz) reflect a combination of sympathetic and parasympathetic ANS outflow variations, while changes in the HF band spectral power (0.15–0.40Hz) reflect vagal modulation of cardiac activity. The MF/HF power ratio is used as an index for assessing sympatho-vagal balance.

The time domain and frequency domain measures and methods described above were initially developed and further refined to meet automation needs and to keep pace with the evolution in processing capabilities offered by the most current computer and microprocessor technology available. One such quantum refinement addresses the time varying characteristics of the autonomic influence on cardiac activity and the transient changes in heart rate response to these regulatory influences. Through the use of advanced signal processing algorithms such as short-time Fourier transform, joint time-frequency distributions and wavelets, the dynamic spectral properties of HRV have been investigated during transient episodes characteristic of various physiological and clinical states.

257

A further level of sophistication was provided to HRV researchers through the use of complimentary analysis techniques that addressed the non-linear complexities and deterministic nature of the control system regulating cardiac activity. These non-linear methods include chaotic analysis, information domain measures such as approximate entropy, detrended fluctuation analysis and heart rate turbulence analysis. All of the above mentioned methods for analysing HRV are important in their own right and have provided unique physiologically relevant information about cardiac rhythm and its regulation. It is only through widespread use and validation of these existing methods and continued development of more advanced techniques that combine engineering and mathematical concepts with biology and medicine that the true potential of HRV analysis be realised and its clinical relevance fully understood.

II. VARIATIONS IN HEART RATE

Under steady state conditions, the specific oscillations of the heart rate reflect the beat-to-beat autonomic control of SA node activity. The SA node, which is the dominant pacemaker of the heart, is enervated by both sympathetic and parasympathetic nerves. Sympathetic nerve activity increases the heart rate, while parasympathetic nerve activity slows it [1]. Clinically measured variations of the heart rate have shown modulations at low, medium and high frequency [6]. These oscillations are of cardiovascular origin and are pseudo periodical. They repeat themselves in time, with a period which oscillates around a certain mean value even when no rhythm disturbances are present. These oscillations are now recognized as physiological rhythms, representing neuro cardiac regulation of blood pressure and heart rate [7].

Changes in blood pressure in normal healthy persons show spontaneous oscillations of the heart rate in a narrow around 0.1 Hz known as the Traube-Hering-Mayer (THM) waves. It has been established that these HR oscillatory waves are generated by the blood pressure control system that causes switching on-off of the baroreceptor reflex [6]. The frequency oscillations of the heart rate (HR) reflect neuroregulatory activity [6]. In this context, the heart rate variation power spectrum (HRVPS) has been studied [8], and provides a noninvasive measure of the autonomic nervous system function. Studies have documented the repeatability of HR power density at rest and its alterations due to mental loading, orthostatic stress, forced respiration, post-myocardial infarct as well as following heart transplant, to help autonomic tone [6, 7].

A. Heart Rate Response in Supine and Standing Positions

Under resting conditions, beat-to-beat variation in the duration of the R-R interval of the EGG in healthy subjects exhibits periodic variation. The change from horizontal to vertical position brings about the influence of gravity on circulation. The test is easily performed by asking the subject to lie quietly on a couch for at least five minutes, then stand up unaided as quickly as possible, and remain standing thereafter for at least one minute. After standing, there is an immediate increase in heart rate (HR), and then a subsequent decrease is observed in normal people. The increase in HR is mediated by the vagal nerves, since it is abolished by atropine and not by propranolol. The decrease in HR is due to a vagal reflex caused by a sympathetically mediated vasoconstriction. The increase in the HR is quantified by measuring the maximum increase during the first 15 seconds compared to the HR in the supine position. The decrease in HR is quantified by measuring the RR interval ratio in the 15 and 30 seconds after standing (RR max / RR min) [8]. Unfortunately different values for this ratio are used as standards by several investigators.

B. HR Response to Deep Breathing

Under resting conditions, beat-to-beat variation in duration of the R-R interval of the ECG from healthy subjects exhibits periodic variation, which is referred to as respiratory sinus arrhythmia (RSA). The origin of the Respiratory sinus arrhythmia (RSA) is still not clear. It is generally agreed that it is mainly mediated by the parasympathetic nervous system, since atropine greatly reduces its degree [6]. The sympathetic nervous system has a minor role to play in RSA, since blocking it with propranolol leads to a slight reduction of the RSA, which is more evident in standing than in the supine position. There is still no consensus on the method or on the way the response is quantified or on the limits of the reference values.

In most tests, RSA is measured when the subject lies quietly and breathes deeply at a rate of six breaths per minute; this rate produces maximum variations in HR [7]. In most studies, RSA is quantified as the mean difference between the maximum and minimum HR during consecutive deep breaths, which can be expressed either in beats per minute (BPM) or in seconds. Another way of expressing RSA is by the mean value of the ratio of the six longest RR intervals to the six shortest intervals.

III. RR INTERVAL DETECTOR

For HRV analysis we require an ECG recorder and RR interval detector as an analog front end. This section discusses about one such design developed for the RR interval data acquisition.

In this system the clamp electrodes are used to measure the ionic potentials generated at the limbs. Fig. 1 shows the physical appearance of these clamp electrodes. Clamp Electrodes enable quick, secure and reliable ECG leads. Intricate and often painful fixing of ECG electrodes is a thing of the past with clamp electrodes. The large contact area of the Clamp Electrode guarantees secure ECG leads. All that has to be done is to apply some medesign Electrode Spray and open and close the clamp. Clamp Electrodes are also easily fixed in emergency situations and are easy to clean. The gentle pressure makes the electrode difficult to detect for the patient. Staffs do not have to fiddle with tightening straps and the ECG is easy to handle. The Clamp Electrode is easily and quickly fixed to arms or legs and no tightening strap is necessary. One Set contains Clamp Electrodes in red, yellow, green and black. It is Suitable for adults as well as children. They are made from antistatic plastic with a silver/silver chloride electrode. The Clamp is made from plastic with surgical steel contact.

Fig. 1: ECG clamp electrodes.

Fig. 2 shows the block schematic of an analog ECG amplifier cum R-peak detector circuit, which converts the ECG signal into R-peak pulses. These pulses are further processed by the microcontroller and programming software on the computer to plot the instantaneous HRV plot. The HRV program also calculates time domain measures like heart rate, mean NN and SDNN. It performs spectral analysis to plot the graph of HRVPS and calculates the different parameters from HRVPS.

The signal obtained from the clamp electrodes is connected to the ECG preamplifier which is built by making use of AD620 and AD705 ICs.It provides a low amplitude distorted ECG waveform. The voltage follower is included for impedance matching and to avoid the loading effect. The low pass filter having cut off frequency of 16 Hz filters

out high frequency noise. The two stage ECG amplifier is included to provide an overall gain of 1000 to obtain an ECG signal up to 2 volt amplitude. At the output of an ECG amplifier we get a clear undistorted analog ECG waveform which is then sent to ADC in data acquisition system (DAS).The ECG signal is also applied to an optoisolator which provides patient isolation along with isolated synchronised pulses corresponding to the R waves in ECG. These pulses are sent to the counter in the DAS which measures the duration between consecutive R waves and sends this data to the computer through the serial port. These pulses are also applied to trigger input of monostable multivibrator which produces a pulse of 429 ms width for each R wave in ECG. The output of monostable mutivibrator is used to drive an LED which acts a beat indicator. The DAS consists of microcontroller PIC 18F2550 and serial port driver MAX 232.It was found that the estimation accuracy is mainly determined by the noise and hum interference. The morphology changes of the P-wave influences the wave form occurrence time estimation. Theoretically, it should be P to P interval file, but due to the difficulties associated with automated recognition of P waves, the R wave is chosen. The R-R interval file contains information in both the time and frequency domain. Hence both time and frequency domain analyses can be used to evaluate heart rate variability. It is necessary to look carefully to the wave-form morphology before estimating it for HRV measurement. Therefore lead L1 ECG configuration is selected, which has high amplitude of QRS wave for measuring R-R interval. The R-R interval file is used to get instantaneous heart rate (HR), as HR is the reciprocal of an R-R interval.
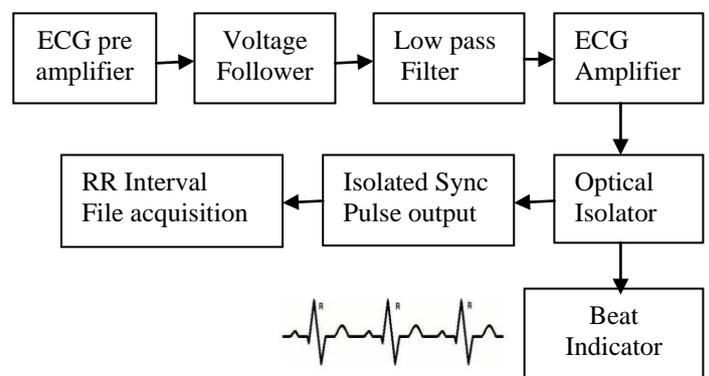

Fig. 2: R peak detector.

IV. SOFTWARE FOR HRV ANALYSIS

The software for the system is developed in VB which provides user friendly graphical interfaces to the doctors along with the database to store patient information and history. The R-R waves coming from the R peak detector will be recorded for 5 minutes for each patient and then sent to the computer by DAS through the serial communication port. The analog ECG signal coming from ECG recorder is sampled at the rate of 8 Hz by the microcontroller and then sent to the computer using serial communication port. The VB software then provides the display of both the ECG signal and HRV signal on the GUI. The software then makes use of MATLAB to calculate the time domain measures like heart rate in BPM, average heart rate for 5 minutes, mean NN, variance of NN and SDNN.The power spectrum will be then plotted using FFT. The power spectrum plot depicts power in ms^2 versus Frequency in Hertz. From the power spectrum following parameters are calculated:
Power under Low frequency range (0.00 to 0.04Hz)
Power under Mid frequency range (0.04 to 0.15Hz)
Power under High frequency range(0.15 to 0.40Hz)
Sympatho Vagal balance ratio which is the ratio of mid to high frequency powers. The logical flow chart for the system operation is as given in fig. 3.
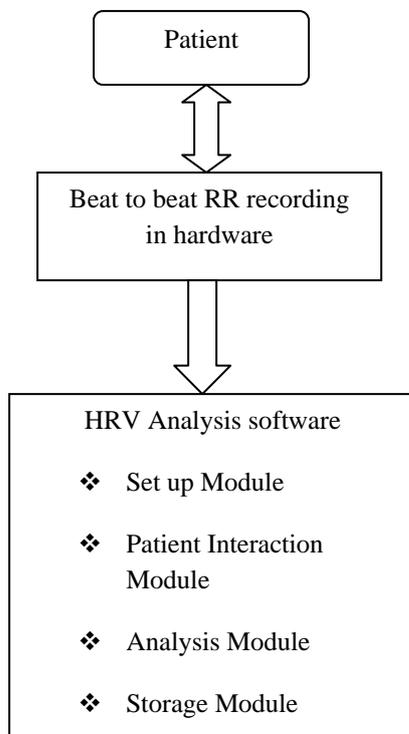

Fig. 3: Logical flow chart for system operation.

The software developed for this application will display the information in various screens. The Startup Screen will appear as soon as the user starts the application. This screen shows up the Various Tabs which the user of the HRV Analysis Software can access. The four main tabs supported are:
1) Setup Tab,
2) Patient Interaction Tab,
3) Analysis Tab and
4) Storage Tab.
Each of these tabs allows for specific functionality to be accessed of the software, the details are as below:

A. Setup

This Tab has a Port setting frame which allows basic port access with Port selection by means of the list box which presents a list of available ports. Open & Close Port functionality is supported; when the port is open there is a GREEN LED symbol which turns RED when the port is closed. The selected port is also listed on screen.
The status of Sampling is also presented is it stopped? or currently active. If active then the time passed after start of sampling is listed.
A Simulate signal check box is provided which allows the ECG microcontroller Hardware to simulate some Waveforms so that the communication between PC and the ECG Hardware and the Graph presentation of the Data Received can be tested/ Verified.
The Next frame in this Tab is the Serial Data Frame which shows the Data communication by presenting the packets exchanged between the PC and ECG Hardware. The outgoing Data from the PC is presented in blue colour and Incoming responses or Data Packets are presented in Red.
Note that most Command buttons except the Stop sampling and Exit Application are Disabled, this ensures that User cannot open or close port while sampling is in progress. The Test Hardware button provided in the software allows the user to test the ECG recorder for the connection. The Next button provided in this tab allows the user to go to the next tab in the software which is the patient interaction tab with graph frame to display the incoming ECG or HRV signal.

B. Patient Interaction

This Tab has a Graph frame which is used to display HRV or ECG waveform while it is being sampled by the Microcontroller hardware system. The Show ECG and Show HRV buttons are provided to select the waveform to be displayed. The default waveform displayed is HRV waveform. The name of the waveform displayed is also shown in this tab along with the corresponding waveform. The microcontroller sends the data to

260

the PC in three channel format. The first channel indicates ECG units, the second channel indicates Whether RR interval is detected or not? When RR interval is detected it sends 1 else 0. The third channel indicates the value of detected RR interval. Since we have used 8 Hz sampling rate for ECG signal there will be eight values consecutively displayed in the ECG channel corresponding to one value in RR interval. All these three channel values are also displayed in this tab along with the graph. This Tab also has the Sampling time section indicating the current sampling time lapsed or sampling stopped status. Using the Setup and Patient Interaction tab the user can Setup the Port and interact with the Patient by Starting or Stopping sampling. Also Testing Hardware connectivity or Quitting Application Command Buttons are available. There are Previous and Next Navigation keys available for moving between the four Tabs, when the user is on First (Setup) Tab the Previous key is disabled and when the user reaches the Last (Storage) tab the Next key is disabled. In case of Clicking the Test / Start /Stop /Start with Simulate selected Command buttons the corresponding packets are sent by the PC over serial port hardware and the incoming packets are populated in to the Serial Data Frame in RED colour. Also the data from packets is decoded and saved in a data File named – HRV_FILE.txt.

C. Analysis

This Tab has a Save file button which allow the User to Save Patients Data and Calculations for the purpose of later use. Also the Load file button can be used to reload a saved file back into HRV software. This tab supports the Analysis based on Time and frequency domain, which allows the user to Select and evaluate specific HRV parameters for Analysis. The Process HRV button in this tab calls the MATLAB program named process PSD.m to calculate the time and frequency domain parameters based on the acquired or loaded RR interval file. This Tab also has a Graph frame which displays HRV power spectrum for the patient.

The next frame in this tab is Time domain measures which displays the time of recording, the number of NN samples in the loaded RR interval file, heart rate in BPM for every minute of recording, average heart rate over a recording period of 5 minutes, mean NN value in ms, variance of NN values in ms and SDNN value in ms.

It also has frequency domain measures frame which displays the values of various components obtained from short term spectral analysis of HRV for 5 minutes. The values displayed are total power in ms^2, LF power, MF power and HF power in ms^2, along with the peak power in each band and the

corresponding peak power frequency. The MF and HF powers are also displayed in normalised units which reduce the effect of changes in total power on these components. The sympatho vagal balance which is the ratio of MF to HF power and indicates the influence of the two branches of autonomic nervous system on HRV is also displayed in this frame. The MATLAB program developed for the analysis tab is given below.

```
% delete old output and Processing had done flag.
dos 'del HRVParmOut.txt'
dos 'del HRVPPSD.txt'
dos 'del HRVPSD.bmp'
dos 'del HRVDone.txt'
dos 'del HRVFFT.txt'
dos 'del HRVFFT.bmp'

% Read Input from File
NNSamples = dlmread ('HRVInput.txt');
 sprintf ('Read in %d samples',
 length (NNSamples))
Sample Count = length (NNSamples);
Sum (1) =0;
for j=2: SampleCount
    Sum (j) =Sum (j-1) +NNSamples (j-1);
end
 Mins=round (Sum (Sample Count)/60000);
if Mins >5
    Mins = 5
end
 for M=1: Mins
    Detect (Sum>60000*M) =1;
    BPMIndex=find (Detect==1);
    BPM (M) =BPMIndex (1)-1;
    clear Detect BPMIndex
end
BPM
 for M=Mins: 1:2
     BPM (M) =BPM (M)-BPM (M-1);
end
 AVGBPM5=mean (BPM);
 MeanNN=mean (NNSamples);
VarNN=var (NNSamples);
STDNN=std (NNSamples);

 % Compute FFT
FreqCount=256;
 FFTNN = fft (NNSamples, FreqCount);

% Output post process
Pyy = FFTNN.* conj (FFTNN) / FreqCount;
f = (0 :( FreqCount/2)-1)/FreqCount;
 figure
plot (f (1 :( FreqCount/2)), FFTNN (1 :
(FreqCount/2)))
 set (get (gca,'Title'),'FontName','FixedWidth')
set(get (gca,'Title'),'FontWeight','Bold')
set (get (gca,'xlabel'),'FontName','FixedWidth')
set (get (gca,'xlabel'),'FontWeight','Bold')
```

261

```
set (get (gca,'ylabel'),'FontName','FixedWidth')
set (get (gca,'ylabel'),'FontWeight','Bold')
title ('FFT Samples')
xlabel ('frequency (Hz)')
 Print -dbmp256 'HRVFFT.bmp'
close (1)
 dlmwrite ('HRVFFT.txt', FFTNN)
Pyy (Pyy==max (Pyy)) =0;
 figure
plot (f (1:FreqCount/2),Pyy(1:FreqCount/2))
title ('PSD Frequency content')
 set(get(gca,'Title'),'FontName','FixedWidth')
set (get(gca,'Title'),'FontWeight','Bold')
set (get(gca,'xlabel'),'FontName','FixedWidth')
set (get(gca,'xlabel'),'FontWeight','Bold')
set (get(gca,'ylabel'),'FontName','FixedWidth')
set (get(gca,'ylabel'),'FontWeight','Bold')
 xlabel ('frequency (Hz)')
ylabel ('Power ms^2');
 print -dbmp256 'HRVPSD.bmp'
close (1)
 dlmwrite ('HRVPSD.txt', Pyy)


% process for band selection
LFMax = 0.04
MFMax = 0.15
HFMax = 0.4
 for j=1:length (f)
   if f (j)<=LFMax
     fLF (j) =f (j);
     PSDLF (j) = Pyy (j);
   else
     if f (j)<=MFMax
       fMF (j) =f(j);
       PSDMF (j) =Pyy (j);
     else
       if f (j)<=HFMax
          fHF (j) =f (j);
          PSDHF (j) =Pyy (j);
       end
     end
   end
end


 % Find Total Power
PSDsum =sum (Pyy);


 % Find Max power in each band


 % LF band
Max1=find (PSDLF==max (PSDLF));
LFPeakf = fLF (Max1 (1));
PsumLF =sum (PSDLF);


% MF band
Max1=find (PSDMF==max (PSDMF));
MFPeakf = fMF (Max1 (1));
PsumMF =sum (PSDMF);
```

```
% HF band
 Max1=find (PSDHF==max (PSDHF));
HFPeakf = fHF (Max1 (1));
PsumHF =sum (PSDHF);
PeakP= [max (PSDLF),
max (PSDMF), max (PSDHF)]
Power= [PSDsum, PsumLF, PsumMF, PsumHF]
PeakF= [LFPeakf, MFPeakf, HFPeakf]


% write Freq & Time Domain Parameters
OutputVar=[PeakP,Power,PeakF,Mins,SampleCou
nt,MeanNN,VarNN,STDNN,AVGBPM5,BPM];
dlmwrite ('HRVParmOut.txt', OutputVar);
 True1=1;
dlmwrite ('HRVDone.txt', True1);


 % go back
exit
```

D. Storage

This Tab again has a Save file button which allow the User to Save Patients Data and Calculations for purpose of later use. Similarly the Load file button can be used to reload a saved file back into HRV software. The Clear record button is used to delete the previous saved record of the patient. This tab supports the Patient Information like Name, Address and Other Contact details etc. to be feed in or reviewed along with Doctors Contact Information. The file is saved in text format which contains the RR interval information over a recording period. The path for saving of file can also be selected from this tab.

The figures 4 to 7 indicate the various conditions in these developed tabs.
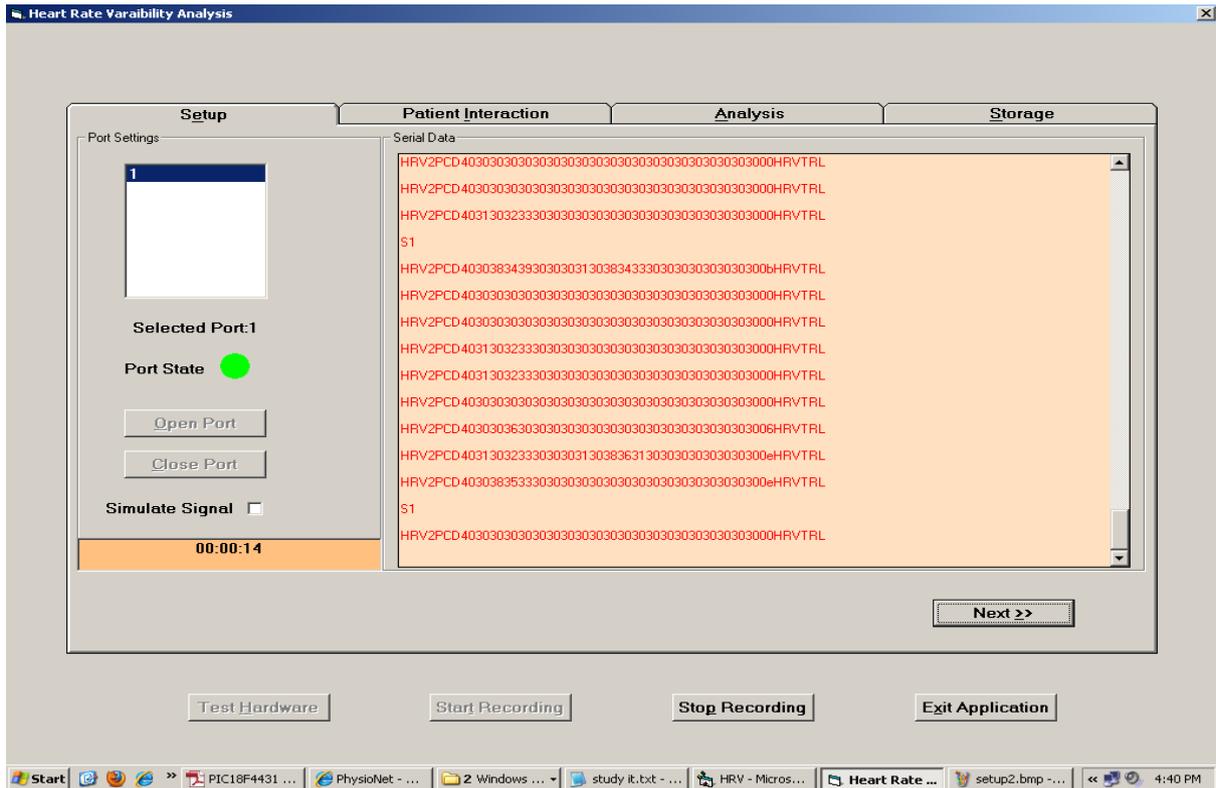
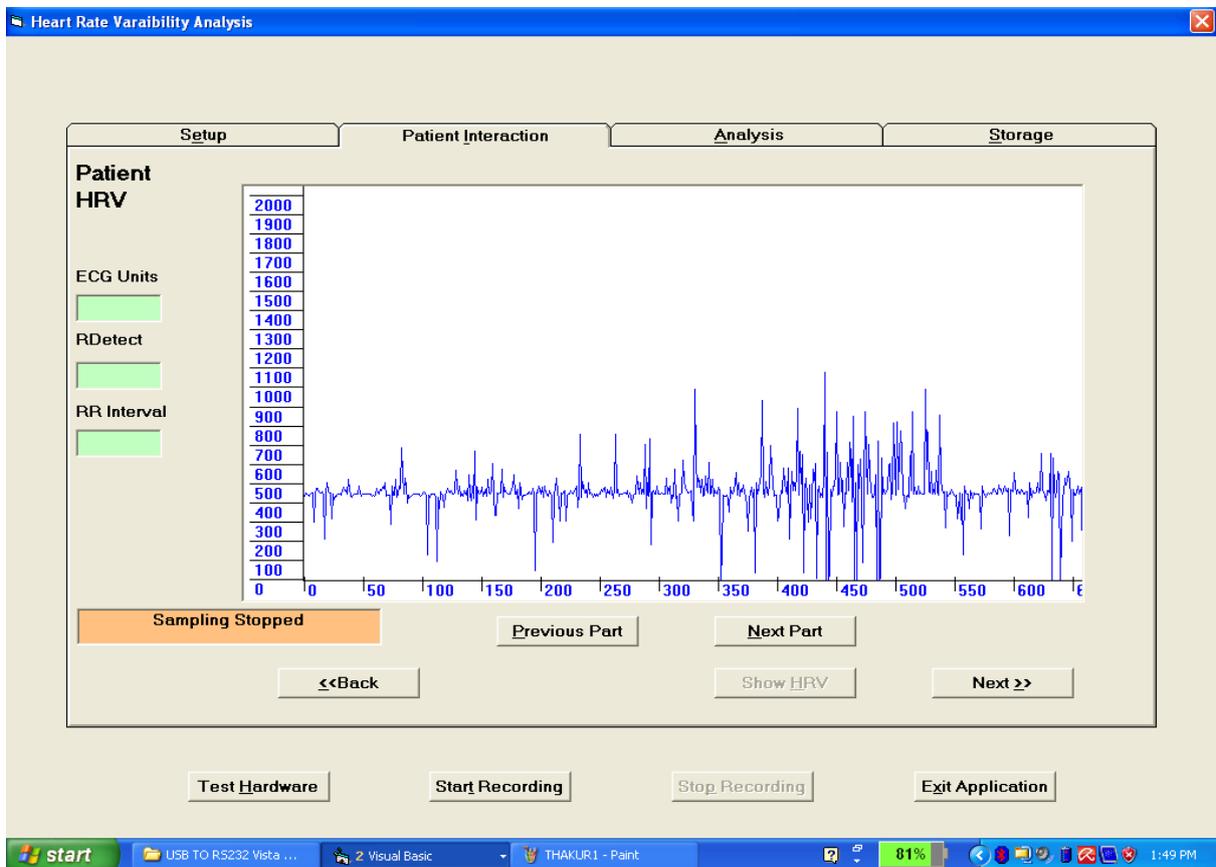Fig. 4: The Setup tab with com 1 port open and sampling started.

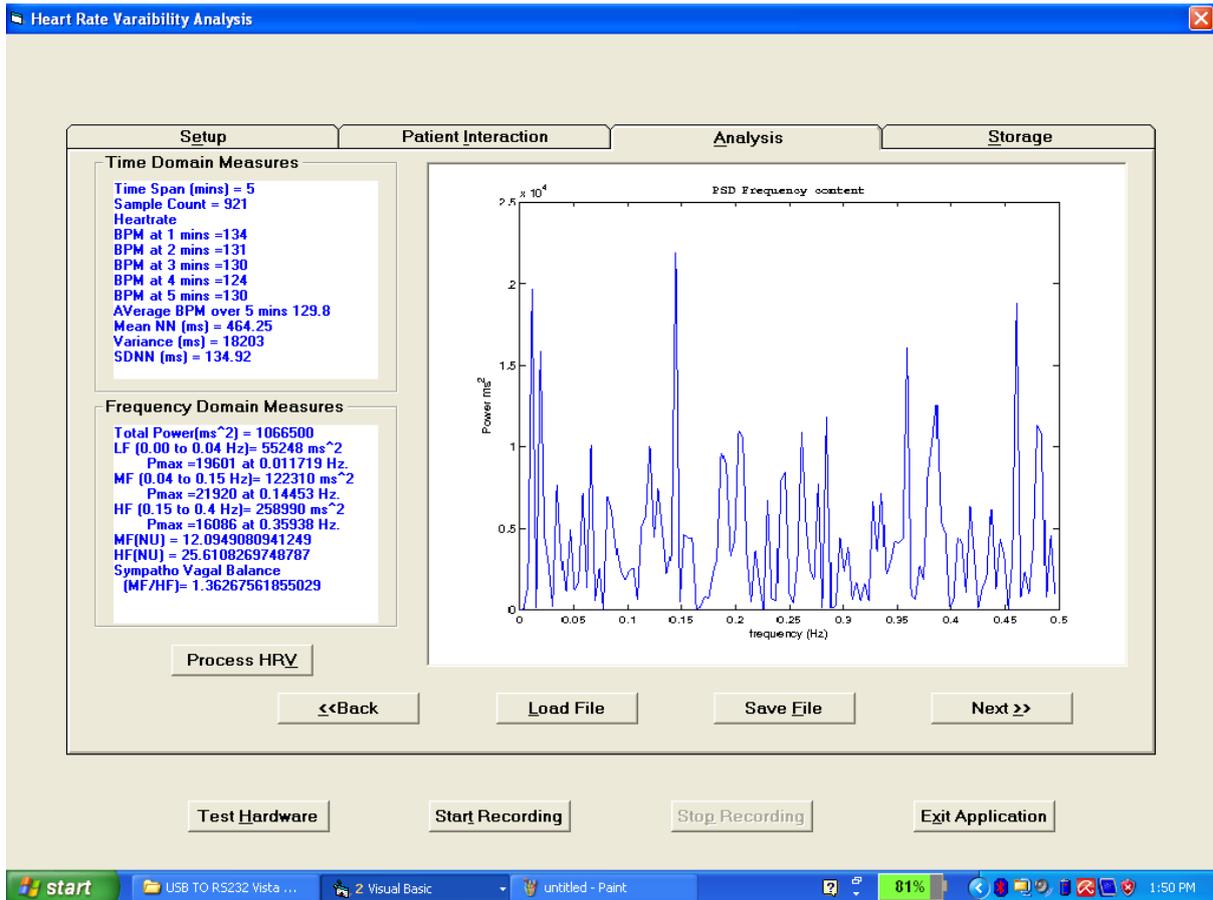Fig. 5: Patient interaction tab with patient HRV displayed.

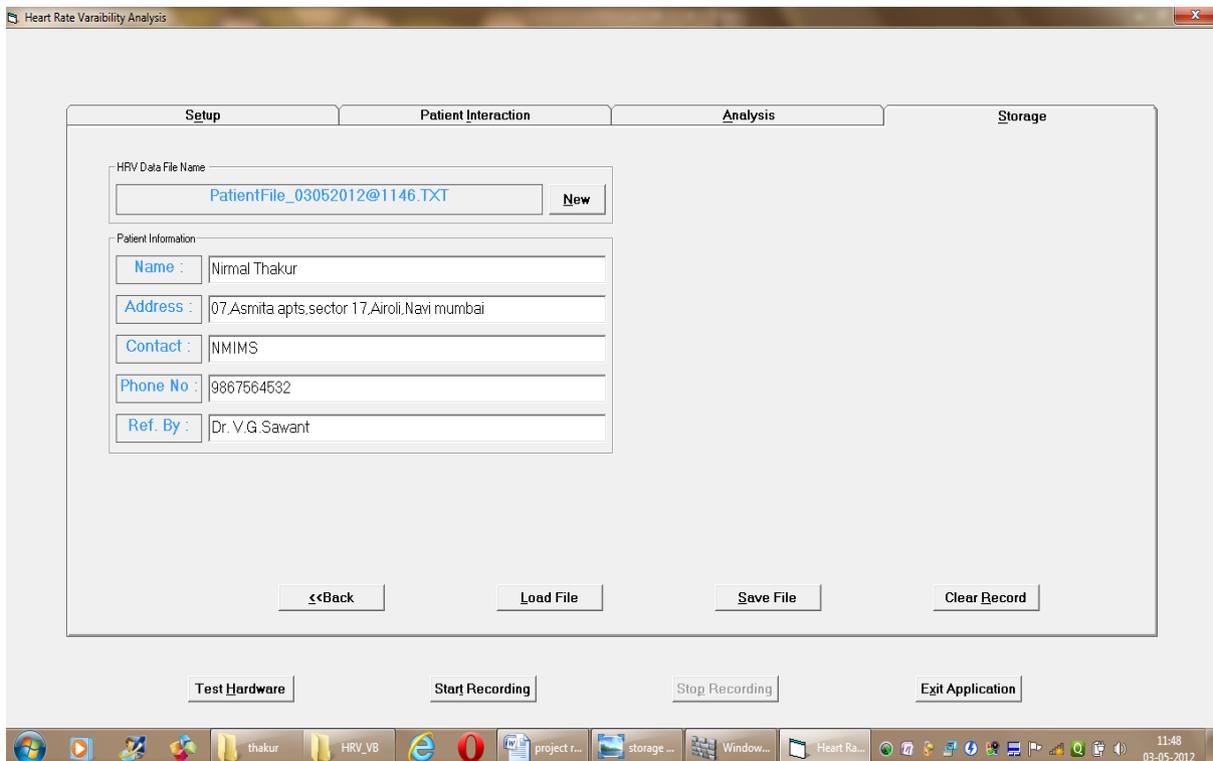Fig. 6: Analysis tab with HRVPS, Time & Frequency domain measures.

Fig. 7: Storage tab to store the patient data.

264

V. RESULTS

The fig.8 (a) and 8(b) presented below indicates the HRV graph and HRV power spectrum obtained for patient with MIT_BIH Arrhythmia. While fig. 9(a) and 9(b) indicates the HRV and HRVPS obtained for patient with normal heart rate variations. Both the results are obtained from the RR interval samples recorded over a period of 5 minutes. Looking at the very nature of the HRV graph the doctor can very easily and primarily differentiate between the normal and abnormal heart rate variations. The software also provides HRVPS and various time domain and frequency domain parameters calculated from HRV which further helps the doctor for detail diagnosis.
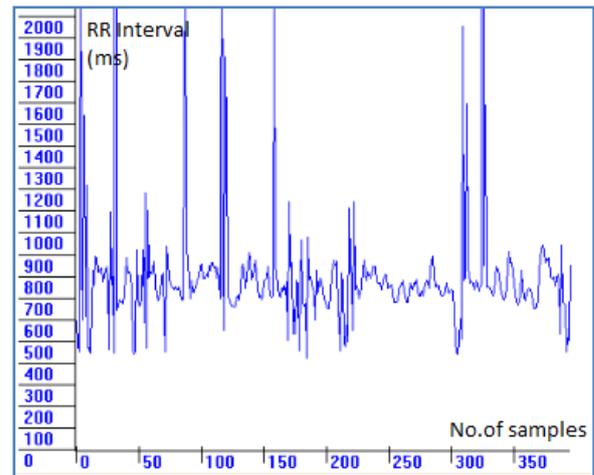

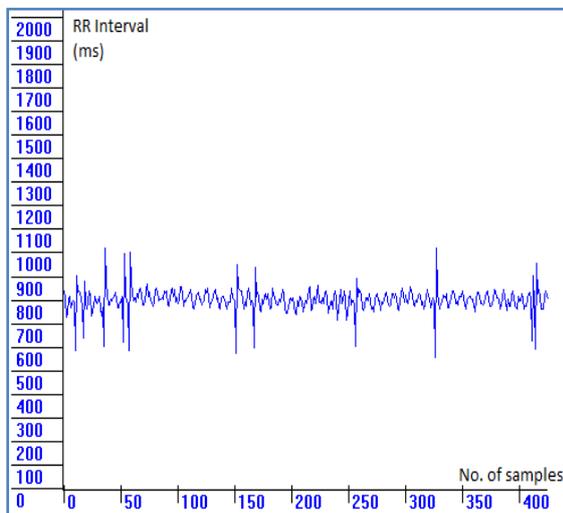Fig. 9(a): HRV for patient with normal Heart.

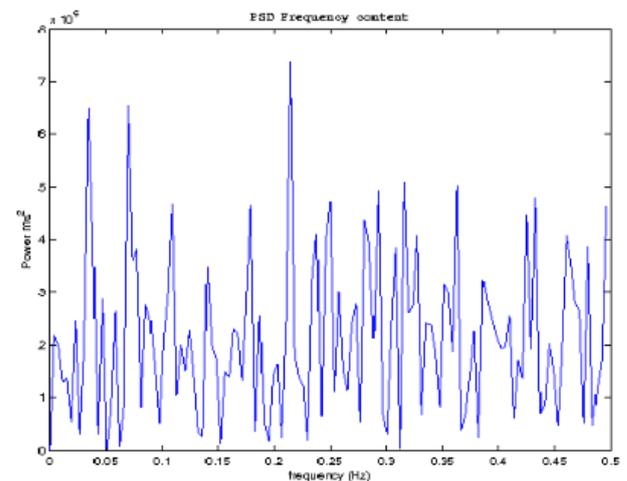Fig. 8 (a): HRV for patient with MIT_BIH Arrhythmia.
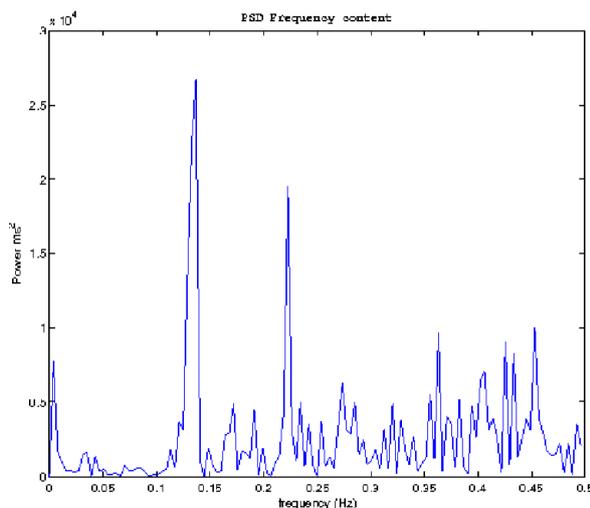

Fig. 9(b): HRVPS for patient with normal Heart.

VI. CONCLUSION

Heart rate variability analysis is increasingly becoming an important tool in cardiology, because it constitutes a non-invasive and convenient method to diagnose cardiac patients. It can provide measures of sympathetic and parasympathetic function of the autonomic nervous system.

HRV has considerable potential to assess the role of autonomic nervous system fluctuations in normal healthy individuals and in patients with various cardiovascular and noncardiovascular disorders. HRV studies enhance our understanding of physiological phenomena, the actions of medications, and disease mechanisms. The developed software for HRV system is user friendly and would provide an economical and efficient solution to the doctors for the assessment of risk in cardiovascular disorders; assessment of physical fitness; documentation of benefit for cardiac, chiropractic, or orthopaedic rehabilitation.

Fig.8 (b): HRVPS for patient with MIT_BIH Arrhythmia.

265

REFERENCES

[1] Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer, "Biomedical Instrumentation and Measurements", Prentice – Hall of India Private ltd.Second edition, pp. 92,292 (1980).

[2] Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology "Heart rate variability. Standards of measurement, physiological interpretation, and clinical use."1996 Mar; 17(3), pp. 354-381.

[3] Drs Tarun Chandra, Donovan B Yeates *and* Lid B Wong "Heart Rate Variability Analysis – Current and Future Trends" Business briefing Global healthcare 2003, pp.1-5

[4] Pomeranz M, Macaulay RJB, Caudill MA, Kutz I, Adam D, Gordon D, Kilborn KM, Barger AC, Shannon DC, Cohen RJ, Benson M. "Assessment of autonomic function in humans by heart rate spectral analysis". *Am J Physiol.* 1985; 248:H151-H153.

[5] Pagani M, Lombardi F, Guzzetti S, Rimoldi O, Furlan R, Pizzinelli P, Sandrone G, Malfatto G, Dell'Orto S, Piccaluga E, Turiel M, Baselli G, Cerutti S, Malliani A. "Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympathovagal interaction in man and conscious dog". *Circ Res.* 1986; pp. 59:178-193.

[6] Issam El Mugamar, K.D. Desai, Sulatan Abdul Ali, Mohammed Saeed, Amin Fikree, S.D. Bhagwat: "Computerized Reliable Detection of Diabetic Autonomic Neuropathy", Proc. Of International Conference on Recent Advances in Biomedical Engineering – 94, Hyderabad, India (1994), pp.321-325.

[7]. Fallen, E.L., D. Nandogopal, S. Connonlly and D.N. Ghista, "How reproducible is the power spectrum of heart rate variability in health subjects?" Proceedings of International Symposium on Neural and Cardiovascular Mechanisms, Bologna, Italy (May, 1985), pp.41-45.

[8].Kamath, D.N. Ghista, E.L. Fallen, D. Fitchett, D. Miller and R. McKelvie, "Heart rate variability power spectrogram as potential noninvasive signature of cardiac regulatory system response, mechanisms, and disorders", in Heart and Vessels,pp. 3, 33-41 (1987).

[9].Kamalakar Desai, Dhanjoo N. Ghista,Issam Jaha El Mugamex,Rajendra Acharya U Michael Towsey, Sultan Abdul Ali,Mohammed Saeed, M. Amin Fikri,"DAN detection by HRV power spectral analysis", pp. 3-14 (2010).

[10] Noel Jerke "The complete reference Visual Basic 6".First edition 22nd reprint 2005, pp.187-247.

Nirmal D. Thakur has received B.E. in Industrial Electronics Engineering from Amravati University in 2002, M.B.A. in Human resources management from IGNOU in 2011, and M.Tech. in Electronics Engineering from NMIMS University, Mumbai in 2012. He has more than 8 years of experience in teaching. He is currently working as Lecturer in Electronics Department at Shreeram Polytechnic Airoli, NaviMumbai. He is life member of Indian Society of Technical education (ISTE). His areas of interest are Biomedical Electronics, Industrial Automation, Process Control and Instrumentation. He has 05 papers in National/International Conferences and Journals to his credit.

Manoj S. Sankhe has received B.E .in Electronics Engineering from Pune University in 1996, M.E. in Digital Electronics from Amravati University in 2002, and is currently pursuing Ph.D. from NMIMS University, Mumbai. He has more than 15 years of experience in teaching & 1.5 years of experience in industry. He is currently working as Associate Professor in Electronics Department at Mukesh Patel School of Technology Management and Engineering, SVKM'S NMIMS University, Mumbai. He is life member of Indian Society of Technical education (ISTE). His areas of interests are Biomedical Electronics, Electronics Circuit analysis & Design and Neural Network & Fuzzy Systems. He has 05 papers in National / International Conferences and Journals to his credit.

Dr. K.D. Desai has received B.E. in Electrical Engineering from V.J.T.I., Mumbai University in 1970, M.E. in Electrical Engineering (Computer Science Specialization) from V.J.T.I., Mumbai University in 1985 and Ph.D. in Technology from V.J.T.I., Mumbai University in 1995. He has more than 25 years of experience in teaching & 13 years of experience in Industry. He is currently working as Director and Principal at K.C.college of Engineering Thane, Mumbai University. His areas of interests are Biomedical Electronics, Telecommunication & Industrial LASER Applications. He has 09 papers in National / International Conferences and Journals to his credit. Currently he is guiding two Ph.D. students at MPSTME, SVKM'S NMIMS University.