5. Data Acquisition & Analysis

Overview

This chapter explains the process of data acquisition and various user interface panels for performing acquisition and analysis. The process of peak detection, manual connection for selected points, interpolation for equidistance samples and obtaining power spectrum density for respiration rate signal and respiration amplitude signal with poincare plot are explained. The power spectrum shows low, medium and high frequencies and amplitudes with its area.
5.1 Data Acquisitions

For acquiring the data from the subject/patient, the subject/patient is hereby informed to take rest for 20-30 minutes if he is tired other wise 10-15 minutes. After that, the patient is informed about the test, working of the instrument. The instrument is not hazardous and does not have any disadvantages/problems for the health due to this measurement/instrument, as Ethical Committee of MGM's Medical College and Hospital have permitted to collect the data for the analysis purposes. It is also informed that the data is collected approximately for 5 minutes to do the analysis. The patient is informed to lie on the bed so that the electrodes are placed/put/stuck on the both arms and chest. Two green and two red electrodes are on arms and one yellow and one violet are placed on the chest in parallel/in line. To see that all electrodes are properly placed and well stuck. Then run the program/execute the program file. The respiration variability front panel will be seen on the screen. The user has to start with reset button so that the system will reset the hardware, to avoid the confusion of previous data overlapping. The gain of the instrument is also to be seen and must be seen as one. If gain is one then go ahead other wise adjust the gain to one if it is half or two. The user has to use the calibration and patient mode alternately for calibrating the instrument and seeing the working of the program. Once the calibration is done the user has to use the “New patient” by clicking the button of mouse, for filling the patient information with unique ID number as required. Then, “Submit” button will submit the patient information with that unique ID otherwise “Cancel” will go back to main panel without considering the information.

Toggle the Start button to start the instrument for acquiring the patient respiration signal. The monitor starts showing the respiration signal with the time i.e. number of samples per second, and how many seconds are completed and date. The screen shows 30 seconds data i.e. 3000 data points as it acquired 100 samples per second. After 30 seconds, the screen displays a signal and again starts from beginning i.e. from starting on screen but actually it is the next sample of 3000. Like that it will record/collect 256000 samples for 256 seconds. If user toggles the stop button the data collection stops other wise it will collect up to 300 seconds and then stop. Then
user has to use the "Save" button to save the data and information of the subject/patient with same ID otherwise the data and information will not be stored on the PC. The user has to take care of removing surface/disposable electrodes from the patient/subject, and discard them appropriately.

"Load" button loads the data; for that it asks the ID; user has to type the correct unique ID of the patient. Once the proper ID is given, load panel shows the patients information and then use the "load" button to load the data, otherwise use "cancel" button to cancel that ID. Immediately the main panel shows the respiratory signal, respiration amplitude variability signal and respiration rate variability signal.

user has to see that the signal from the 0 to 256 seconds is continuous within a range; he can also see that the red and green color marks of peak and valleys are marked alternately or not. User has also to see if all peaks and valleys are marked by red and green color lines or not. If not, then the user has to mark the peak by using small red-cross from respiration panel by adjusting the small red-cross to left side of the respiratory signal peak and click the mouse; then the red line will mark the peak values only (i.e. line between base and peak of the respiration signal). Similarly for the valleys to use the same procedure but use the valley position to get green line. If the red and green lines of peaks and valleys are extra (i.e. more than the actual peaks or valleys), then use small green-cross cursor from respiration signal panel to cancel/delete these peaks/valleys by clicking the mouse button.

Due to add/delete the correction has to be done for the respiration amplitude variability and respiration rate variability, for this mouse button is used to click the "Correction" button from the main panel. Immediately after, the correction is done in respiration amplitude variability and respiration rate variability signals, which shows on the front panel with red and green graphs. For power spectrum, Poincare graph and the results for calculating different frequencies, "P_spectrum" button is to be clicked with the mouse. The above results are seen on the power spectrum panel. These graphs and different parameters are helpful for the diagnosis of lung diseases such as obstructive/restrictive, tuberculosis, bronchial asthma, etc. with stage.
5.2 Flow Chart for Back

![Flow Chart Image]

Figure 5.1 Flowchart of controller side backend program.
5.3 Front End Software

PC side software, Respiration Variability Analyzer (RVA) is designed in LabWindows CVI ('C' for virtual instruments), from National Instruments. Software is completely User Friendly and GUI based. CVI is most suitable software for development of real time/virtual instrument. It gives all required controls for user interface like buttons, textboxes and graphs. Attributes and properties of all controls can be set or predefined in some cases and also can be controlled through software. A number of separate panels can be added for reducing complexity of user interface and efficient output. The Assessment of Pulmonary Function by Respiratory Variability Analyzer is focused on the data acquisition from the subject/patients and detection of variability of respiration rate, respiration amplitude, distinguishing between obstructive and restrictive respiratory disease, from the same signal. Since the application of HRV differs from abroad software. Main screen of RVA is as shown in Figure 5.2 Patient name is displayed in right top corner with time and date.

Real time ‘Time’ and ‘Date’ is displayed on right bottom corner for record management. Whenever the record is saved current date and time is also saved in the same patient file for further analysis. A separate timer is used to continuously update Date and Time with real system time.

Pressing “New Patient” button invokes Patient Registration Form in which all personal information-Patient ID, Name, Age, Gender Height and Weight can be filled in as shown in screen below.

Patient ID is a key field which stores all details of a particular patient which can be retrieved only by entering the same Patient ID. Figure 5.3 shows patient registration form for personal details and unique patient ID number.

“Submit” button creates a file which stores all patient details and goes back to main screen. Pressing “Cancel” button goes back to main screen without storing any information.
"Start" button is a toggle key for Start and Stop. In Start mode it enables sampling timer which sends data request command to microcontroller with predefined time interval. Time interval is set as 10 ms, therefore sampling frequency is 100 Hz. In response to data request controller sends one byte which is sampled respiration signal. Signal is plotted as Respiration graph with respect to real time. 3000 samples are plotted in one screen graph, i.e. 30 sec. Pressing the same key again disables sampling timer and also stops plotting of graph. "Save" button stores Respiration signal in patient data file. Figure 5.4 shows the data stops after 13.5 seconds, save the data and displays/open again the same ID. Patient information and Respiration signal can be retrieved by pressing "Load Patient" button. It invokes a screen for asking Patient ID for unique patient identification as shown in Figure 5.5. By pressing "Open" displays patient's detailed information and "Load" displays
Patient's respiration signal which can be observed from beginning to end by pressing mouse button to left and right.

![Respiration Variability Analyser](image)

**Figure 5.3: Patient registration Form**

"Load Patient" button performs actual operation on active respiration signal of that ID, the respiration signal, respiration amplitude signal and respiration rate signal displays on main screen (front panel). Peaks and valleys are marked by red and green lines from base to respiration signal. The user has to see that the all peaks and valleys are marked (red and green) alternately to all the respiratory signals from 0 to 256 second. If yes, then the respiration amplitude variability signal and respiration rate variability signal are correct as per the design/software. Otherwise click the red-cross cursor from the respiration signal panel and manually mark the peaks.
putting the cross cursor to left side of the peak inspiration signal and click the mouse button; the red line will be drawn from base to the peak. Similarly for the valley, moves the cross cursor to left side of the valleys of expiration and right click the mouse button; a green line will be drawn from base to the valleys of the respiration signal. Similarly user has to check from starting to end of the signal and repeat the procedures for marking the red and green markings to the respiration graph. Click the “correction” button from the front panel, so that these peaks and valleys (amplitude of red and green lines) data is stored in the respective arrays, which are required for getting more information and accuracy of respiration amplitude variability, respiration rate variability, and their spectrums.

\[ \text{Instant respiration rate is } = \frac{60}{(\text{temp} \times 0.01)}; \] ..................................(5.1)

Where, temp is the time interval of one cycle.

**Figure 5.4: Load the subject data with Patient ID number.**
Figure 5.5: Respiration signal of subject for 13.5 second

Index of the peaks detected red marked position is stored in an array. Difference between two successive marked positions gives number of samples between two breaths. The peaks will get the maximum values of the end of inspiration and starting of expiration. Thus the total number of peaks will be equal to the number of breaths within the 256 seconds time interval. Number of the samples is only of number of peaks and these are less than 256. Plotting of these values gives us a
respiration amplitude variability graph. Thus the sample signal is not uniform for 256 seconds. Signal is studied for 256 seconds. Time between two peaks is not constant. It varies as respiration rate varies. So respiration amplitude signal can not be samples at equal interval of time unless we have a continuous respiration amplitude signal. To obtain a continuous respiration amplitude signal with uniform time scale signal is interpolated using technique of SPLINE Interpolation. Our Sampling frequency is 100 Hz, so for 256 seconds we have 25600 samples for respiration amplitude signal. This signal is again sampled with sampling frequency of 1Hz to obtain 256 samples for frequency domain analysis of respiration amplitude signal. SplInterp-Performs a cubic spline interpolation of the function $f$ at a value $x_{val}$,

\[ \text{Interp\_Val} = AY_i + BY_{i+1} + CY_i'' + DY_{i+1}'' \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldot
these values with respect to time gives us a respiration rate variability graph. Signal is studied for 256 seconds.

Figure 5.6: Respiration signal, respiration amplitude signal, and respiration rates signal after the corrections made in the peak and valley.

Time between two actual respiration rate values is not uniform; it is inversely proportional to the value of respiration rate, so plotting of respiration rate signal vs. time is not uniform. Respiration rate value is plotted for that particular instance of time which is only intermediate value; all other values are calculated by SPLINE
Interpolation. This gives a uniform respiration rate signal, which is plotted with respect to time as shown in Figure 5.7.

*Figure 5.7: Respiration signal, respiration amplitude signal, and respiration rates signal of the original respiration signal (without corrections).*

Peak detected for each breath is the end of inspiration and starting of expiration while in valleys it is vice versa i.e. starting of valley is inspiration and end of valley is expiration. That means valley to peak is inspiration time of one breath and peak to valley is expiration time of the same breath. Thus the total numbers of breaths are
calculated. Total time required for inspiration and total time required for expiration is also calculated. Ratio of these finds the subject/patient lung disease as normal, obstructive or restrictive.

\[
\text{AutoPowerSpectrum} = \text{FFT}(X) \, \text{FFT}^*(X) / n^2 \\
\text{........... (5.7)}
\]

The Figure 5.8 shows the power spectrum and Poincare graph with some important parameters.

*Figure 5.8: Power spectrum of Respiration Amplitude Signal, and Respiration Rates Signal and Poincare graph for the Respiration signal.*