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Automatic Feature Extraction in Acceleration Plethysmography

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Abstract
PPG is a non-invasive, inexpensive and convenient diagnostic tool which is used to determine the skin blood flow by means of infrared light. The Accelerated Plethysmography (APG) which is derived from the photoplethysmography uses the second derivative of the waveform of the digital plethysmography to stabilize the baseline and to separate components of the waveform more clearly than the first derivative. In this paper, the data of 36 Subjects has been recorded using BIOPAC MP System and Acqknowledge Software. Initially the parameters were calculated manually which is a time consuming and error prone process. This research article explains an automated method of detecting the salient features of PPG in the form of algorithm. The algorithm developed give 100% accurate results for APG of normal young subjects.

1. Introduction

Plethysmography is a non-invasive indicative technique which is used for screening with several arterial in conjuction with venous pathologies. The principle of plethysmography is based on the graphical recording of any kind of elemental change in body with respect to each heartbeat. In contrast to this is the photoplethysmography(PPG), which is used for recording any change in reflection of light from the shift in number of red blood cells in the cutaneous microcirculation[1].

Classification of Photoplethysmography on the basis of signal processing method for velocity is shown in Figure 1:

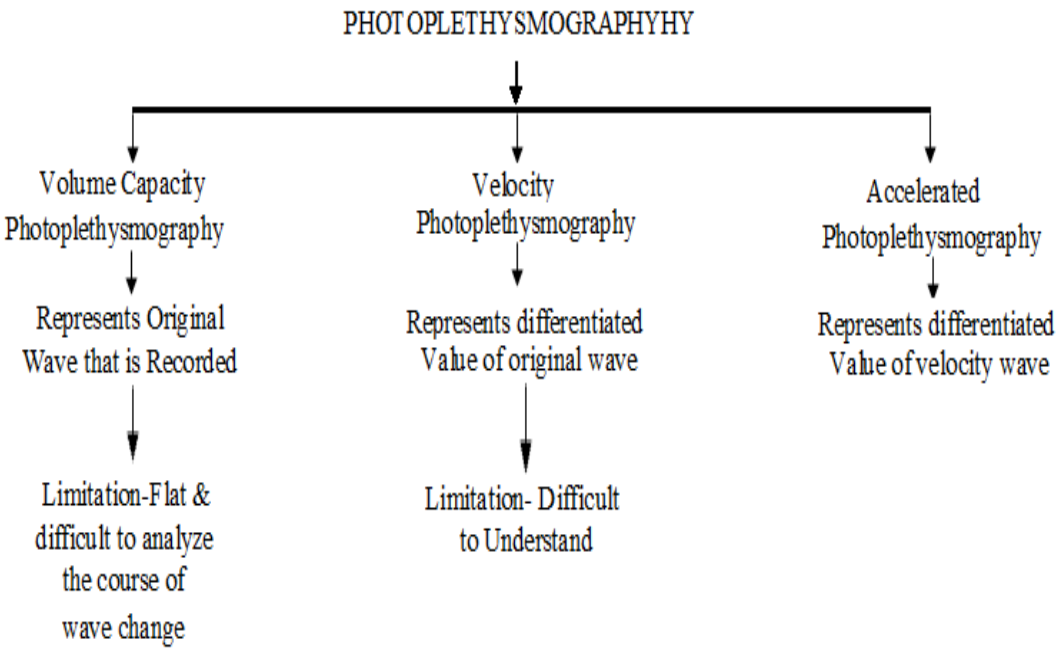

Figure 1: PPG classification by velocity method

2. Accelerated Photoplethysmography(APG)

This is a dimension tool for the evaluation of vascular retrogradation by differentiating "Volume capacity plethysmography" two times[2]. This is also known as Second Derivative of finger photoplethysmography (SDPTG) composition of Volume Capacity Photoplethysmography, Velocity Photoplethysmography and Accelerated Photoplethysmography is shown in Figure 2.

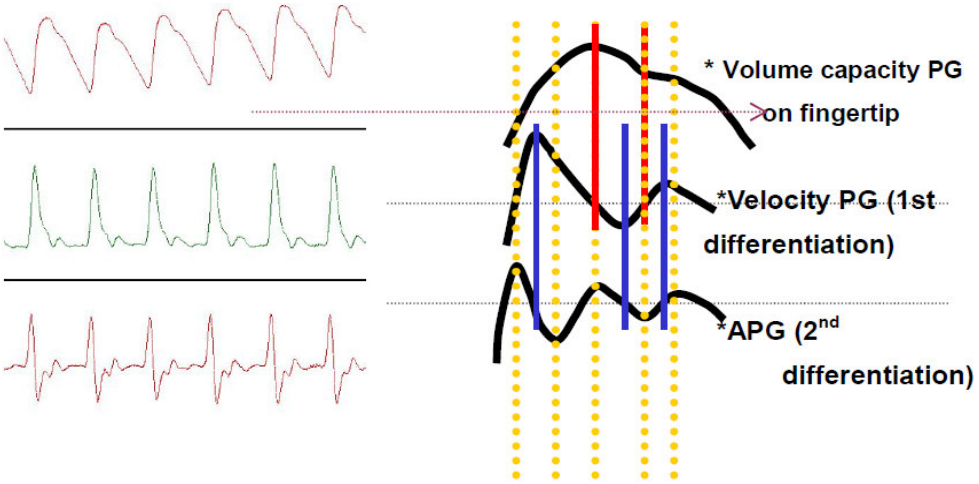

Figure 2: Comparison of Volume Capacity Photoplethysmography, Velocity Photoplethysmography and Accelerated Photoplethysmography

2.1 Background of Invention

The background of invention of Second Derivative of finger photoplethysmography (SDPTG) or Accelerated photoplethysmography (APG) is depicted in self explanatory diagram shown in Figure 3.

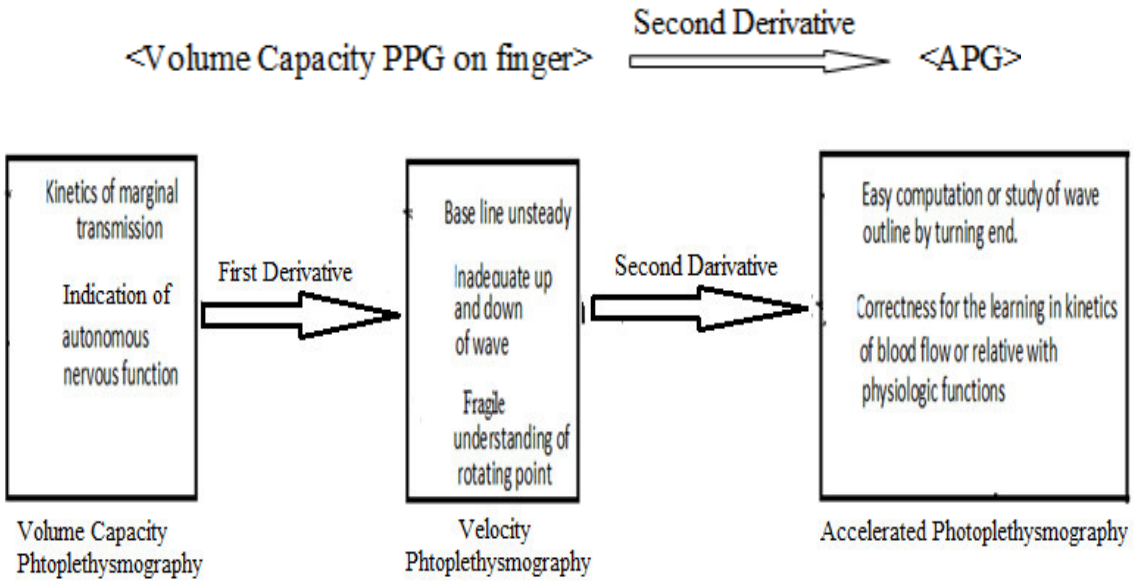

Figure 3: Classification of PPG on the basis of problems in Volume Capacity Photoplethysmography and Velocity Photoplethysmography

3. Analysis of SDPTG Waveform

The second derivative of the finger photo plethysmography is SDPTG. It consists five main parts as shown in Figure 4, from a to e: initial positive (a), early negative (b), re-increasing (c), late re-decreasing (d) and diastolic positive (e). From these determinants, the following parameters can be calculated: b/a ratio, c/a ratio, d/a ratio, e/a ratio[3,4].

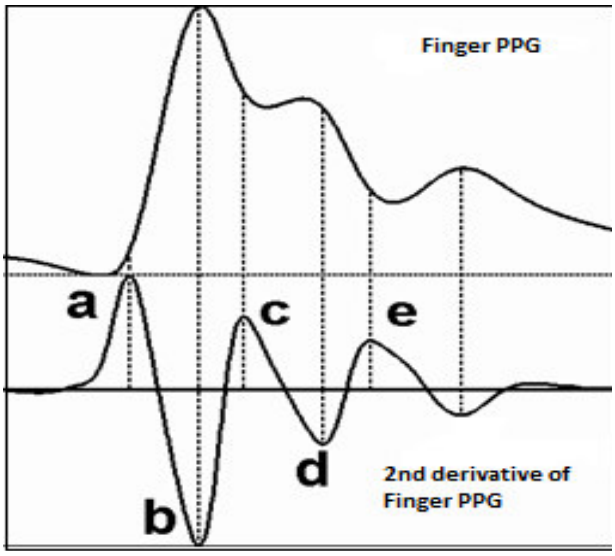

Figure 4: SDPTG (Second Derivative of finger photoplethysmography)

PPG signal is obtained by putting a photodiode sensor and light emitting diode around any of the fingers, traditionally index finger[5]. Signal from PPG and its derivatives finds several applications. A traditional way of identifying Ayurveda doshas based on questionnaire has found many scientific references[6-9]. This identification is also done by studying PPG waveforms and their derivatives[10-17]. PPG studies also find applications in Biometrics[18].

4. MP system and Acqknowledge

The MP system hardware offers an adjustable means for the research and training needs. The modular, commanding interface structure can be used by means of BIOPAC amplifiers and accessories and with equipment.

MP starter system comprises all software, hardware and documentation that is needed to get started. Amplifier modules, transducers and electrodes can also be added to match the research design. New module for Electrogastrogram, Non-invasive blood pressure measurement, Microelectrode Recording and electrical bio-impedance (cardiac output) are also available here. Each MP system offers changeable sample rates for analog and digital channels, good resolution(16 bit), digital I/O lines,16 analog inputs and 2 analog outputs and 16 online calculation channels. With MP 150 system the high-sped acquisition (400 KHz aggregate), the ability to view and control systems across a network and Ethernet connectivity can be obtained [19].

Acqknowledge software is incorporated with all MP systems. It is an instinctive, interactive program that gives the instantly outlook, measure, convert and analyze data. It helps in performing complex data acquisition, triggering, stimulation and automated analysis using simple pull-down menus and dialogue boxes. There is no need to learn a programming language and new protocol for working on this software. It has online analysis settings, filters and transformations that provide real-time feedback. The wide variety of off-line analysis tools can also be chosen in this software. Multiple display options are existing during and after acquisition. Just a click on an icon gives the flip between chart, Scope, X/Y, overlapped segments, histogram or FFT. The software also provides excellence presentation capabilities[20, 21].

5. Data acquisition

For acquiring the data we need to set up the channels first. In our study we have selected 3 modules of PPG100C and PPG100C-MRI with label Index, Middle and Ring respectively. From these 3 modules we get 3 channels namely A1, A2 and A3 for acquire, plot and value with sampling rate set at 250.00 KHz. The channels are selected through set up channel option that comes under the drop down menu of MP150 as shown in Figure 5.

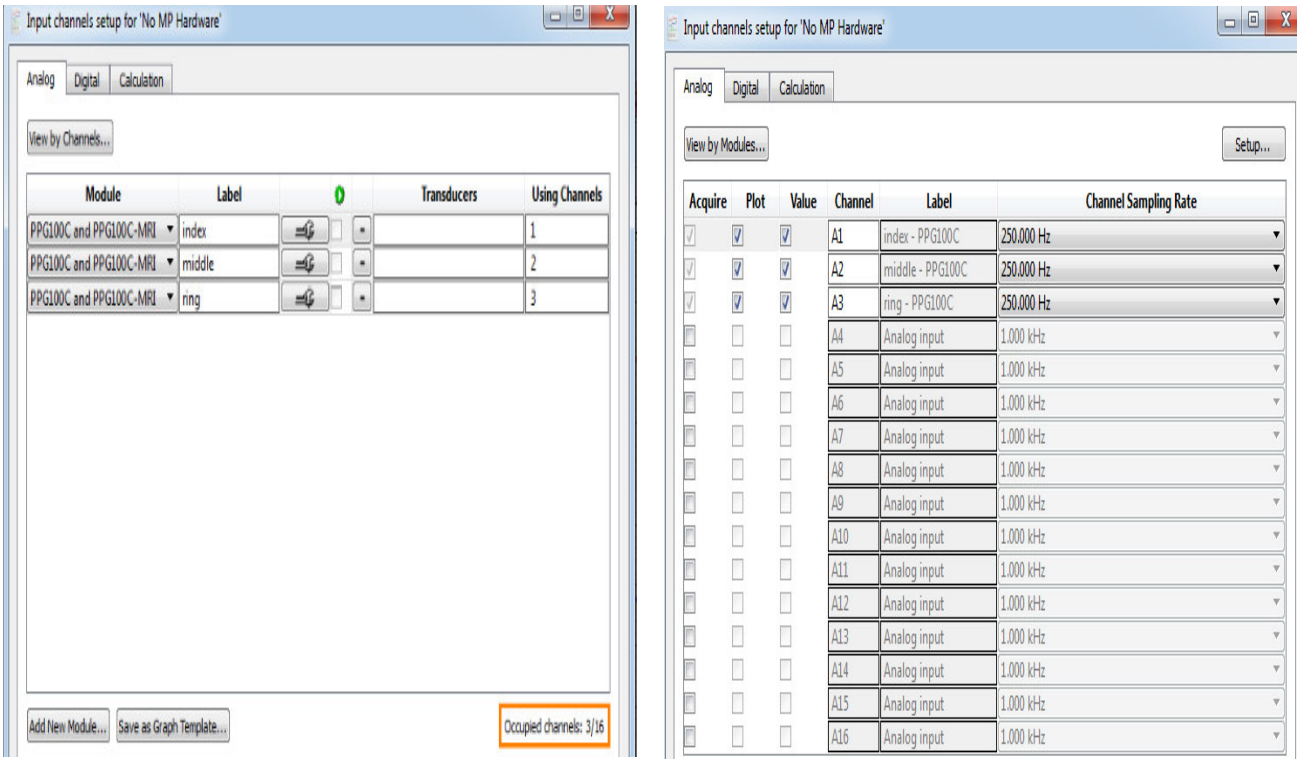

Figure 5: Channels of Acknowledge Software

For recording the data, the 3 PPG sensors are wrapped around the subject's finger that is Index, Middle and Ring finger respectively while the other end of all the 3 sensors are connected to the transducer amplifier module of the MP system. The start button becomes active only when the circular light placed before the start button turns green. The green status of light shows that the MP data acquisition unit is properly connected to the computer. The data is then recorded by clicking on the start button. In our study the finger pulse waveform of 36 subjects is recorded after 1 hour 30 minutes of breakfast but before 10.30 am, of index, middle and ring finger for both the hands respectively. Similarly the data of all the 36 subjects is recorded immediate before and after 15 min of lunch but the lunch should be taken in between 1 to 2 pm. The data is recorded for 30 seconds and is processed for feature extraction. Sample of such a recording is shown in Figure 6.

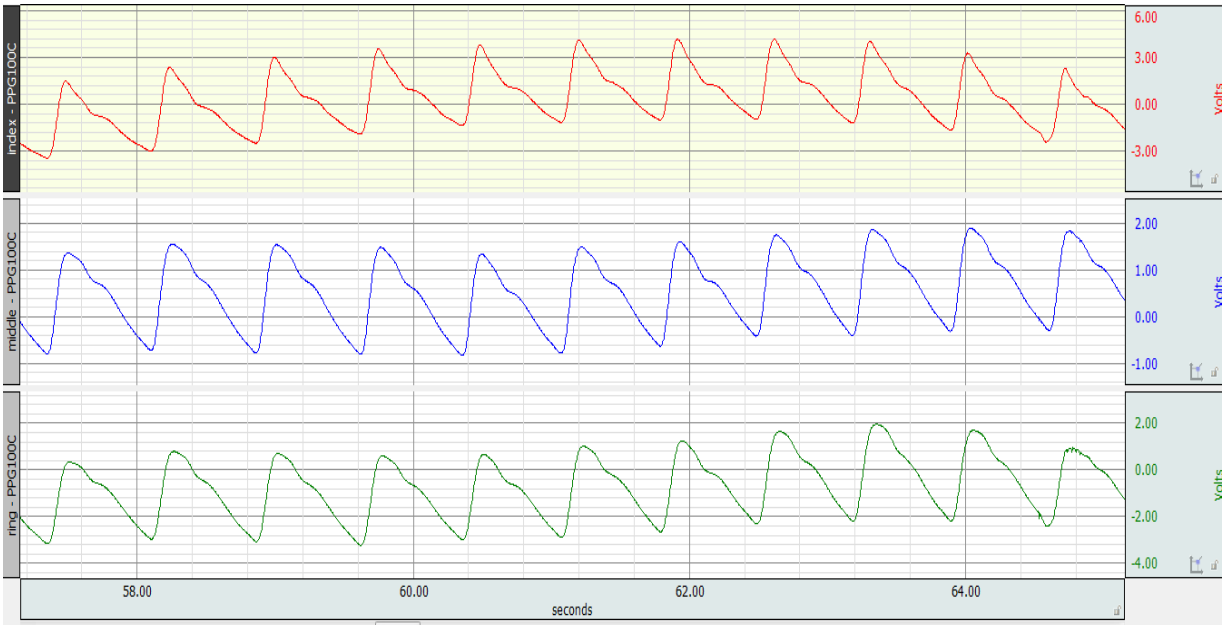

Figure 6: Recorded pulse wave

6. Processing of data

The noise is removed from the recorded data by using digital IIR band stop filter at default line frequency 50 Hz and quality factor 5. After removal of noise the derivate is taken twice at a sampling rate of 25 samples/second. The resultant waveform after second derivative is shown in Figure 7.

Figure 7: Second Derivative of PPG

From second derivative of waveform gives the 5 main features labeled from a to e:

Initial positive(a), Initial negative(b), Re-increasing(c), late re-decreasing(d) and diastolic positive(e) as shown in Figure 4. From these determinants the 4 parameters are to be calculated: b/a ratio. c/a ratio, d/a ratio and e/a ratio.

7. Computer algorithm

Earlier the features were extracted manually by simply selecting the data and with the help of Acqknowledge software. This was time consuming and error prone process. In our study to make the work faster and easier, the features are extracted by using the computer algorithm using matlab programming.

The algorithm is described below:

1. Initially, record the pulses of three fingers simultaneously of both the hands using Biopac MP 150 system.
2. Apply digital IIR Band Stop Filter and took derivative twice.
3. Recorded data is saved in an Excel sheet.
4. Call the excel sheet in Matlab Script File.
5. Find out all the positive and negative peak values.
6. The peak values are stored in two different arrays:
   Array A for all positive peak values
   Array b for all negative peak values
7. Find out range of the highest positive and negative peaks in the entire waveform.
8. Make an Array of these highest positive and negative peaks.
9. If a negative peak occurs after every positive peak then discard the second positive peak and repeat the step for entire waveform.
10. If a positive peak occurs after every negative peak then discard the second negative peak and repeat the step for entire waveform.
11. Plot these highest positive and negative peak values for each cycle.
12. Find out 2 consecutive positive peak values after first highest positive peak from array A.
13. If this process is applied to the entire waveform then go ahead else go to step 12.
14. Find out early next negative peak value after first highest negative peak from array B.
15. If this process is applied to the entire waveform then go ahead else go to step 14.
16. Forever, make a matrix of these five (positive and negative) peak values for the entire waveform.
17. Plot these five values.
18. Let these five values are called a_i, b_i, c_i, d_i and e_i respectively for each cycle.
19. Now, calculate b/a, c/a, d/a and e/a for each cycle also calculate mean and standard deviation of these ratios.
20. Finally make a matrix having columns as a, b, c, d, e, b/a, c/a, d/a, e/a of each cycle and another matrix having three rows which contains the values of mean, Standard deviation and variance.
21. Stop the program.

The images that appears after running the program which are shown in Figure 8-12.

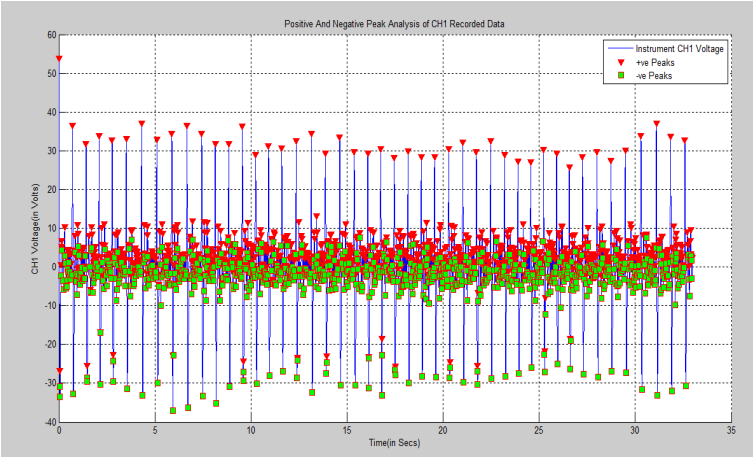

Figure 8: All positive and negative peaks of the waveform

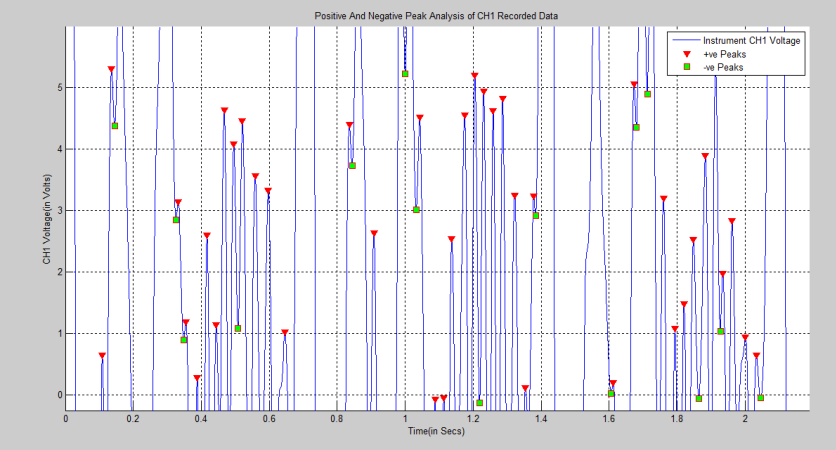

Figure 9: Zoomed View of all positive and negative peaks of the waveform

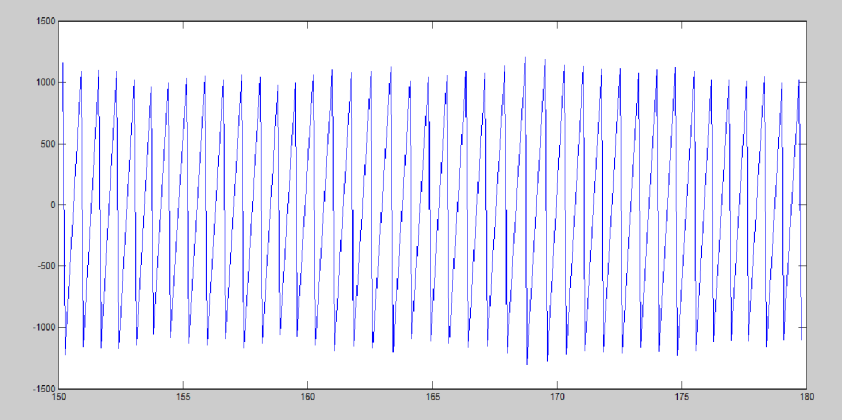

Figure 10: Matrix of highest positive and negative peaks from each cycle

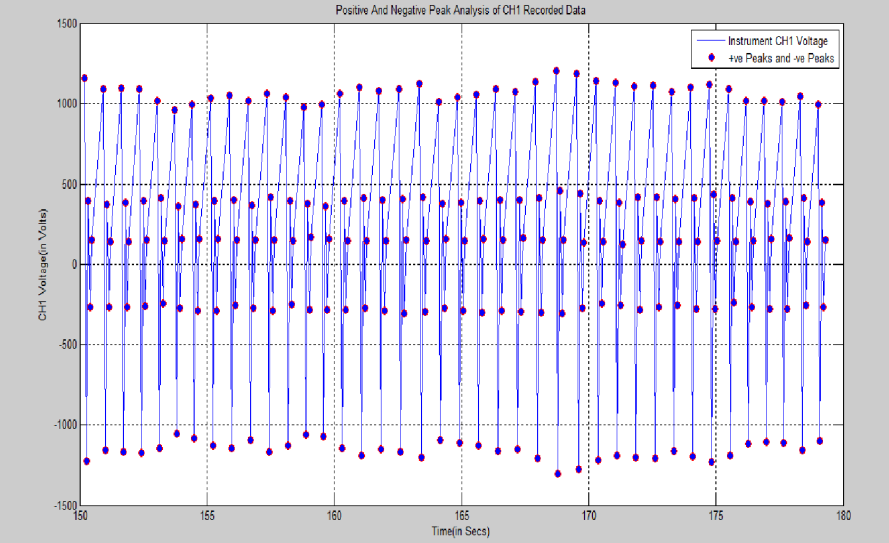

Figure 11: Features of complete waveform

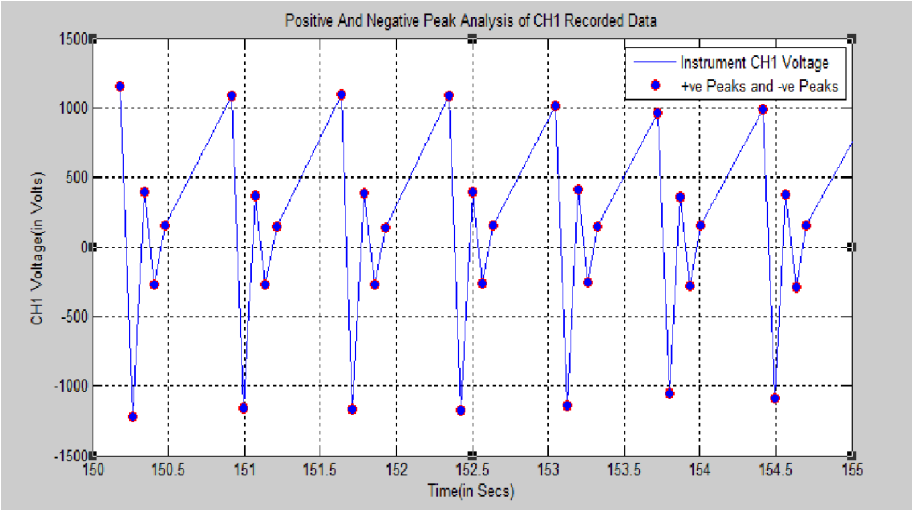

Figure 12: Zoomed view of features

8. Result

The features that have been extracted from the program are also extracted manually. Afterwards the manually and automated values are compared with each other. From the result of comparison the accuracy obtained is 100%.

9. Conclusion

The process of extracting the features manually is very tedious task and error prone. From this work, it may be concluded that the automatic feature extraction makes our work easier. It is time saving and error immune. Further it gives an accuracy of 100%.

10. Future Scope

The present study has identified the features of the normal subjects waveform. It is further proposed that this algorithm needs to be expanded to the abnormal subjects as well.

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