International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Development of Application Software for Features Extraction from Peripheral Pulse Waveform

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Abstract: ***Features extraction from the detected characteristic points of peripheral pulse signal is done for further analysis. In this paper, method of characteristic point detection and extraction of various features such as amplitude and time interval between the points of peripheral pulses has been proposed. The peripheral pulse impedance data has been obtained by Peripheral Pulse Analyzer (PPA). Developed by the Bhabha Atomic Research Centre (BARC), Trombay, Mumbai. Peripheral pulse is due to the blood moving away from the heart and vessels at high pressure. Peripheral pulses are clinically useful in identifying specific vascular pathologies, including peripheral arterial disease, vasculitis, congenital abnormalities, and others. It is observed that the amplitude of characteristics points in diseased subject are slightly lesser than the healthy subjects, in other hand the time intervals are also found to be lesser in diseased subject as compared to the healthy subjects. The features have been extracted through the use of developed application software which has been programmed using the python programming language.***

Keywords: Peripheral Pulse Waveform, Peripheral Pulse Analyzer, Morphological Patterns, Characteristics Point, Feature Extraction

1. Introduction

The electrical conduction and muscle contraction of the heart generate a reaction known as the peripheral pulse, which can be sensed in different areas of the body. Typically, this pulse is assessed by palpating the arteries in the wrist. Blood circulation from the heart and through the blood vessels causes the pulse, which can be detected in various regions of the body. Peripheral pulses are valuable in clinical settings as they help identify specific vascular conditions, such as peripheral arterial disease, vasculitis, and congenital abnormalities.[1]

The Bhabha Atomic Research Centre has developed a computer-based tool called the Peripheral Pulse Analyzer (PPA), which operates on the principle of impedance plethysmography [2]. Impedance plethysmography indirectly measures changes in blood volume within a body segment by monitoring changes in its electrical impedance. Using this technique, the Peripheral Pulse Analyzer generates blood flow patterns and examines physiological variabilities like Heart Rate Variability (HRV) and Blood Pressure Variability (BPV) as significant features[3]. The amplitude of blood flow patterns has been observed to differ between healthy and unhealthy individuals, and these distinct peaks can be utilized for pattern identification purposes.

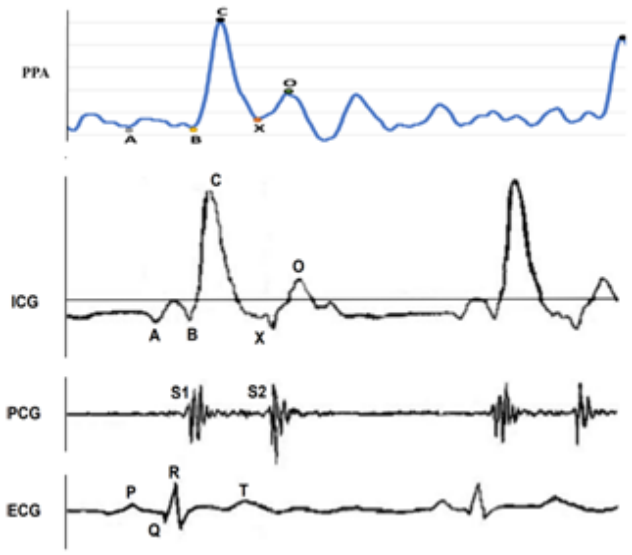

Figure 1: ICG and Peripheral Pulse signal with the characteristic points marked on it, along with the impedance, phonocardiogram (PCG), and electrocardiogram (ECG) waveforms

The characteristic points of peripheral pulses share similarities with the ICG pulse signal. These points, labeled as A, B, C, X, and O, represent significant events in the cardiac cycle [4,5]as shown in Figure 1. The A point is a negative deflection from the baseline and typically corresponds to atrial contraction. The B point appears as a notch just before the rapid upstroke towards its peak, occurring during the first heart sound (S1) and associated with the opening of the aortic valve. During systole, the peak in PPA waveform is referred to as the C point, which is linked to the peak in aortic blood velocity. Following the C point, a valley is observed during the second heart sound

(S2) known as the X point, associated with the closure of the aortic valve. Subsequently, the positive deflection after the X point and before the next A point is called the O point, generally coinciding with the wide opening of the mitral valve.

2. Data Acquisition

Pulse signals from the radial artery are measured using the PPA developed at B.A.R.C, Mumbai, India. The radial artery begins about 1 cm below the elbow joint and passes along the radial side of the forearm to the wrist, where its pulsation can be readily felt as shown in Figure 2. With the subject in supine position, carrier electrodes are applied around the upper arm and the palm while sensing electrodes are applied on the distal segment around the wrist. PPA uses the principle of IP this is indirect assessment of changes in blood volume in any part of the body from changes in the electrical impedance of the body segment. It was first introduced by Nyboer in 1940. [6] wherein a sinusoidal current of constant amplitude (2 mA) with frequency 50-100 kHz is allowed to flow across the wrist of the subject using band electrodes. +The amplitude of the signal thus obtained is directly proportional to the electrical impedance of the body segment[7].

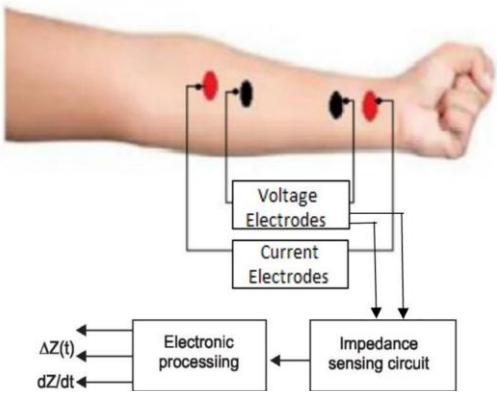

Figure 2: PPA Data Acquisition

The obtained waveforms are sampled at 500 Hz as a time series data[8]. The data is recorded in normal and diseased subjects at Father Muller Hospital, Mangalore, and MGM Engineering College, Kamothe for about five minutes. The subjects are in the range of about 18 to 60 years. Total 400subject's files have been used for the experimental work, which were consisting of 100 healthy and 300 unhealthy subjects. The dataset encompasses various disease conditions, including Cancer, tuberculosis, Arthritis, HIV, Diabetic Mellitus, Cirrhosis, and Hypertension.

3. Methodology

Every pulse waveform under various disease conditions has different characteristic features in terms of amplitude and time intervals.The software is developed as shown in Figure 5 to detect the amplitude and time intervals of characteristics points. Block diagram of application software is shown in Figure 3. Flowchart of algorithm for detection of features is shown in Figure 4.

Initially user need to upload PPA datafile in text format recorded from various healthy and diseased patients. Once the file is uploaded successfully, the Application software will read the uploaded file and plot the graph according to the uploaded data. Then user need to select sample range, software finds the peaks present in the given sample range and denote it as C. It also calculates the amplitude of point C and C-C interval. After C point detection, the application software plot A, B, X and O characteristic points present in the waveform with respect to selected C-C time interval. Then amplitude of characteristic points is calculated as A: minimum value present in 15% of C-C interval before point B, B: minimum value present in 10% of C-C interval before C point, X: minimum value present in 15% of C-C interval after C, O: maximum value present in 10% of C-C interval after X point.

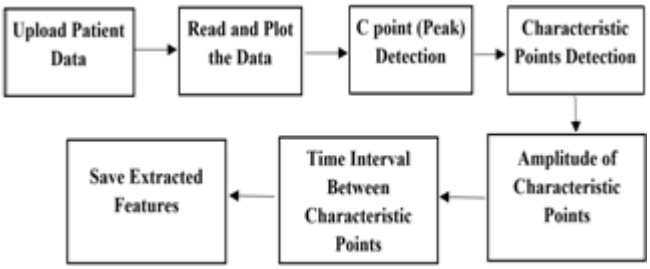

Figure 3: Block Diagram of Application software

Time Interval between Characteristic Points:
Once the characteristics points are detected the application software calculates the Time interval between the points.

Time interval:

1) Point A – Point B
Calculation to find time interval between point A and PointB:
Sample A – Sample B = x sample
Therefore, time interval between A and B is
= x sample x 1 / 500 Sample (1 sec =500 sample)

2) Point B – Point C
Calculation to find time interval between point B and Point C:
Sample B – Sample C = x sample
Therefore, time interval between B and C is
= x sample x 1 / 500 Sample (1 sec =500 sample)

3) Point C – Point X
Calculation to find time interval between point C and Point X:
Sample C – Sample X = x sample
Therefore, time interval between C and X is
= x sample x 1 / 500 Sample (1 sec =500 sample)

4) Point X – Point O
Calculation to find time interval between point X and Point O:
Sample X – Sample O = x sample
Therefore, time interval between X and O is
= x sample x 1 / 500 Sample (1 sec =500 sample)

5) Point C – Point C
Calculation to find time interval between point C and Point C:

Sample C – Sample C = x sample
Therefore, time interval between C and C is
= x sample x 1 / 500 Sample (1 sec =500 sample

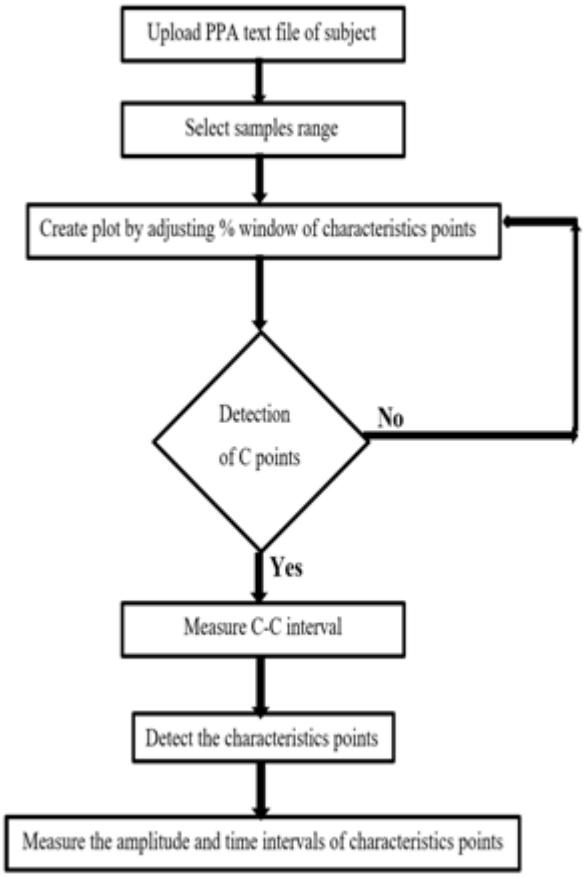

Figure 4: Flowchart of algorithm for detection of features

Figure 5 shows the Graphical User Interface of project working of the GUI are as follows:
Step 1 Upload Waveform:
Click on "Upload File" to add the waveform in text format. The GUI shows the selected waveform, the user can scroll through the waveform by using the arrow buttons.

Step 2 Select Sample Range:
user can manually select the required sample rage by selecting start and end sample.

Step 3 Window % Selection:
window % selection is set as point A 10%, point B 15%, point X 15 and point O 10% by default.

Step 4Display Final Plot:
The final plot is automatically displayed by the GUI according to sleeted parameters (sample range and window % section)

Step 5 Adjust Display:
In some cases,if certain points aren't clearly displayed in the final plot, the user can manually adjust the window for each point for accurate results.

Step 6 Calculate Amplitude and Time Interval:
The GUI calculates and shows amplitude and time interval.

Step 7 Enter Patient Condition:
Users need to input the patient's condition manually.

Step 8 Save Features: by clicking the save button all the data this is the amplitude and time interval values along with patient condition is subsequently saved in excel sheet.

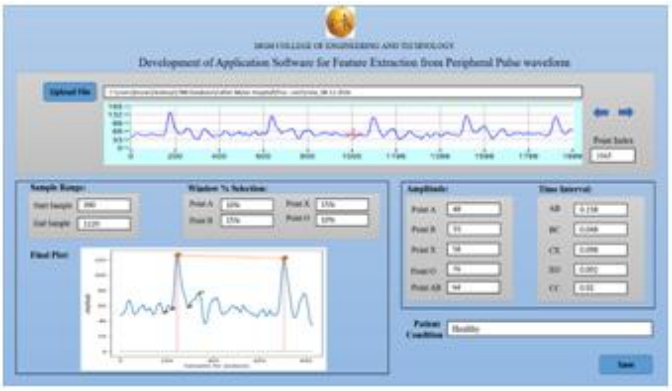

Figure 5: Graphical User Interface

4. Results

The developed application software is utilized for extracting distinctive features, and Table 1 presents the extracted values from peripheral pulses. Various values are observed in peripheral pulses under both healthy and diseased conditions. Notably, there are variations in both features and morphological characteristics of peripheral pulses among patients with different diseases. Amplitude and time interval features of 50 subjects are shown in table 1 and similarly data have been obtained for 400 subjects in diseased and healthy condition. Extracted features values are obtained in excel sheet. Illustrated in table,in diseased condition the average amplitude values of points AB, A, B, C, X, Ois69.9062, 52.9375, 55.62, 152.4375, 38.875, 85.562 respectively. The corresponding time intervals of AB, BC, CX, XO, CCare 0.0983, 0.074875, 0.19925, 0.104438, 0.67850.04respectively. In contrast in healthy condition, the features are as follows: AB, A, B, C, X, O, average values are 64.96667, 57.06667, 57.33333, 127.9, 50.86667, 87.80 respectively, with time intervals of AB, BC, CX, XO, CC being 0.0994, 0.075067, 0.105267,0.117533, 0.814267respectively. It is observed that the amplitude and time interval in most of the characteristics points in diseased subject are slightly lesser than the healthy subjects.

Subject	Sample Range	Amplitude						Time interval				
		AB	**A**	**B**	**C**	**X**	**O**	**AB**	**BC**	**CX**	**XO**	**CC**
Abdul cancer	277	47	44	47	124	29	54	0.04	0.05	0.14	0.04	0.55
Gulabi cancer	411	72	51	51	185	26	106	0.17	0.06	0.23	0.07	0.82
Anthony cancer	402	44	44	43	189	15	126	0	0.07	0.24	0.08	0.8
Bhaskaran cad	474	43	39	39	219	0	137	0.01	0.09	0.11	0.21	0.95
Girijama cad	411	91	68	68	196	50	124	0.12	0.06	0.21	0.08	0.82

Glady cad	458	76	66	75	176	42	0	0.05	0.09	0.18	0	0.92
Aysha Healthy	385	72	67	70	118	57	82	0.04	0.07	0.11	0.07	0.77
Manish Healthy	478	76	73	71	132	55	89	0.06	0.07	0.11	0.08	0.96
Manish Healthy	515	66	65	66	163	50	88	0.02	0.07	0.11	0.1	1.03
Jincy Healthy	328	78	65	73	144	48	101	0.1	0.04	0.08	0.24	0.66
Deny healthy	368	79	66	70	164	43	88	0.11	0.06	0.1	0.11	0.74
Vaishnavi Healthy	310	68	63	68	157	44	91	0.09	0.06	0.09	0.09	0.62
Vaishnavi Healthy	305	74	67	72	149	45	90	0.09	0.08	0.1	0.07	0.61
Dimple A	444	92	77	81	151	64	107	0.12	0.09	0.12	0.08	0.89
Dimple A	518	92	77	82	162	69	111	0.11	0.09	0.11	0.09	1.04
Dipti Healthy	310	72	65	64	143	51	101	0.13	0.08	0.09	0.22	0.62
Hari Healthy	462	73	69	70	130	60	95	0.07	0.06	0.12	0.23	0.92
Hari Healthy	440	77	72	68	154	46	111	0.09	0.09	0.11	0.23	0.88
Rathu Healthy	353	72	66	65	124	59	89	0.07	0.07	0.13	0.19	0.71
Deephan healthy	475	74	67	67	141	53	85	0.17	0.07	0.09	0.1	0.95
Priya healthy	337	74	63	63	138	59	92	0.13	0.07	0.09	0.21	0.67
Pooja healthy	387	71	61	61	138	65	81	0.04	0.08	0.09	0.09	0.77
Jincy Healthy	327	72	60	69	134	50	95	0.1	0.06	0.09	0.21	0.65
Anuradha Healthy	430	68	62	62	159	55	79	0.07	0.08	0.27	0.08	0.86
Anuradha Healthy	408	70	64	64	154	56	84	0.12	0.07	0.26	0.09	0.82
Monica Healthy	377	71	64	63	132	59	78	0.07	0.06	0.24	0.07	0.75
Monica Healthy	368	73	67	67	138	61	78	0.06	0.06	0.25	0.07	0.74
Dimple Healthy	590	80	71	70	152	48	103	0.1	0.08	0.11	0.1	1.18
Anil hypertensive	352	75	58	46	131	46	0	0.18	0.07	0.45	0.07	0.7
Bhalchandra hypertensive	351	74	64	65	111	62	87	0.1	0.12	0.1	0.05	0.7
Anuj Hypertensive	326	73	51	59	121	49	74	0.1	0.15	0.29	0.05	0.65
Jaya Hypertensive	404	67	45	62	89	51	63	0.1	0.1	0.56	0.04	0.81
Laxmi Hypertensive	407	79	64	65	124	43	74	0.1	0.07	0.25	0.08	0.81
Rahul Hypertensive	322	74	68	67	96	61	81	0.14	0.08	0.07	0.18	0.64
Nehe Hypertensive	282	74	69	74	107	68	83	0.05	0.08	0.11	0.05	0.56
Anu A	396	83	58	58	179	55	113	0.16	0.13	0.11	0.08	0.79
Anushka A	352	66	58	62	124	54	88	0.11	0.06	0.28	0.09	0.7

Table 1 extracted characteristic features (Amplitude and Time interval) using app

Harshita A	393	77	46	55	165	56	93	0.12	0.08	0.13	0.08	0.79
Ancy A	351	59	55	56	142	51	89	0.02	0.08	0.24	0.09	0.7
Abhy A	431	72	53	55	188	24	115	0.11	0.13	0.16	0.2	0.86
Hima DM	389	64	43	46	193	18	120	0.08	0.07	0.27	0.09	0.78
Nimitha DM	352	65	48	54	112	46	81	0.16	0.05	0.24	0.06	0.7
Ravikumar DM	325	70	59	62	156	33	90	0.06	0.08	0.22	0.07	0.65
Jecintha HIV	330	78	36	38	180	11	104	0.2	0.09	0.19	0.09	0.66
Lokhnath HIV	371	76	51	61	145	32	74	0.1	0.05	0.09	0.12	0.74
Anil HIV	319	70	57	55	195	16	90	0.12	0.06	0.22	0.07	0.64
Ashwath HIV	270	69	39	53	129	37	96	0.11	0.05	0.11	0.13	0.54
fathima HIV	263	70	45	44	180	21	99	0.1	0.05	0.2	0.09	0.53
Hanume HIV	351	50	41	42	109	34	66	0.06	0.07	0.08	0.08	0.7
Naveen HIV	316	62	55	51	116	29	71	0.12	0.05	0.08	0.2	0.63

5. Conclusion

The developed software can be used for extraction of features from peripheral pulse waveform under healthy and various diseased conditions. The proposed software has provided amplitude and time interval values between characteristics points A, B, C, X, and O. It is evident that the features and characteristics of peripheral pulses exhibit variations between healthy and among patients affected by different disease conditions.

The peripheral pulses can be further studied and more features can be extracted. Different additional characteristic points such as S that is the rising peak that appears just next to characteristic point O, amplitude of that point and time interval can be extracted from the waveform. The extracted features may be further used for developing machine learning model to predict various diseases.

Acknowledgement
The authors are grateful to Dr. Geeta S. Lathkar, Director, MGMCET and Dr. V.G. Sayagavi, Vice Principal, MGMCET for providing continuous encouragement throughout the study. The authors are also thankful to Dr. G. D. Jindal, HOD, BME Department, MGMCET for the continuous support and guidance. Finally, authors would like to express heartfelt thanks to Family and the Almighty for the unconditional moral support, constant inspiration and blessings.

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