ESTIMATION OF BLOOD PRESSURE USING REGRESSION MODEL

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Abstract : Today Health Monitoring has become one of the significant areas to focus upon because of humans are becoming more vulnerable to various kinds of diseases. One of the significant reasons that lead to increased number of deaths every year worldwide is cardiovascular illness. An abnormal high blood pressure or hypertension leads to cardiovascular illness. When the blood circulates in the body it applies a certain force on the blood vessels which is measured as Blood Pressure .Wireless Body Area Network helps in monitoring of a person's healthcare continuously. WBAN is a special purpose sensor network that provides continuous health monitoring of a person through nano/bio sensors. The device known as sphygmomanometer is commonly used to measure blood pressure. But with the growth in IOT and wearable devices the demand of measuring Blood Pressure indirectly (without inflation, deflation of cuff) is increasing day by day. To estimate the Blood Pressure indirectly and in a non invasive manner a method based on Linear Regression has been proposed. Initially the kind of relationship between the R peaks of the ECG Signal with the Arterial Blood Pressure is deduced using correlation. Finally regression is applied to estimate blood pressure.

IndexTerms **- Wireless Body Area Network (WBAN) , Correlation , Regression , Blood Pressure, Electrocardiograph (ECG)**

I. INTRODUCTION

With the advent use of sensors, Wireless Sensor Networks is in great demand. The technology of sensors has been upgraded to such an extent that the smart watches which can monitor certain physiological parameters of a person such as heart rate , number of steps that person has walked etc. are in the most use now a days. However, the stressful and sedentary lifestyle is also leading to various types of diseases, High or Low blood pressure being the prominent among them. Wireless Body Area network which is a subset of wireless sensor network can play a big role for monitoring the health of a person.

In medical domain, the concern for the bedside patients has increased because they often get irritated by so many tests and monitoring such as inflation and deflation of cuff in sphygmomanometer through which blood pressure is monitored. Few conventional methods such as use of sphygmomanometer are being adopted by the hospitals for the patient monitoring but, certain WBAN's have improvised the living of the patients like no longer stays in the hospitals and the doctor could guide the patient through internet by looking at the patient's record and health. This could be an easier task for both the doctor and the patient. People are now well aware of all the upcoming technologies so there is a need to perform some extensive research in the field of health and WBAN.

1.1 Wireless Sensor Network (WSN)

A WSN involves battery powered, self governing, wireless devices called nodes which have processing and sensing capabilities that can monitor any kind of conditions like sound, temperature, pressure etc. Wireless Sensor Networks has spanned all walks of life. The various applications of wireless sensor include Industrial Monitoring, Area Monitoring, Threat Detection, Environmental/Earth Sensing and Health Care Monitoring. Out of all these Health Care Monitoring has attracted all the researchers more due to increase in aging population and the modern lifestyle, the human body is becoming vulnerable towards the diseases such as blood pressure , heart problems etc. The subset of wireless sensor network that is wireless body area networks has proven to be a blessing in healthcare.

1.2 Wireless Body Area Network (WBAN)

WBAN is a unique purpose sensor network which consists of minute diversified biological sensors which are wearable or can be inserted under skin or placed over various parts of the body. These sensors help in measuring changes in a patient's physiological parameters such as blood pressure, ECG, EEG, blood glucose level etc 24*7 as well as detecting emotions such as fear, stress, happiness, etc. The key components of WBAN are sensors which need to be of low frequency as they are deployed on the human skin.

1.2.1 Electrocardiogram(ECG)

The electrical activity in the heart is recorded as Electrocardiogram (ECG). The electrical activity is caused by contraction and relaxation of atria and ventricles in the heart which is represented by P, Q, R, S and T waves as shown in Fig 1.1.The QRS complex is the main line/spike in an ECG.

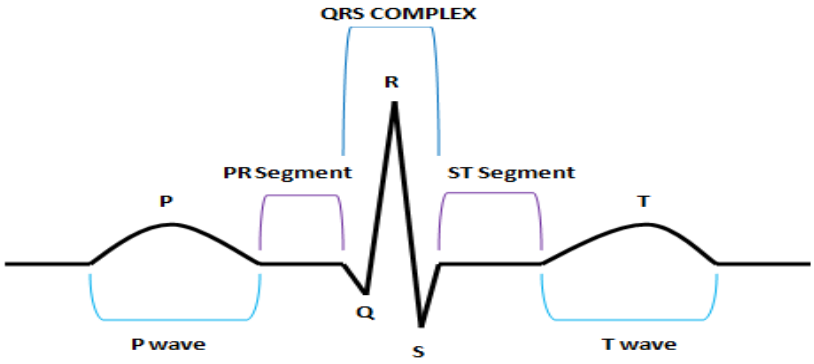

Fig. 1.1 Components of an ECG Wave

P wave Duration < 80 ms
PR Wave: Duration: 120-200 ms
Q Wave: Downward Deflection
R Wave: Upward Deflection.
S Wave: Downward Deflection after R Wave.
T Wave: Duration: 160 ms

1.2.2 Blood Pressure

The movement of blood through the circulatory system takes place due to a force called blood pressure. It is measured between the systolic and diastolic pressures. Systolic Blood Pressure is the highest pressure when the heart contracts whereas when heart relaxes the pressure becomes the lowest and it is referred to as Diastolic Blood Pressure.

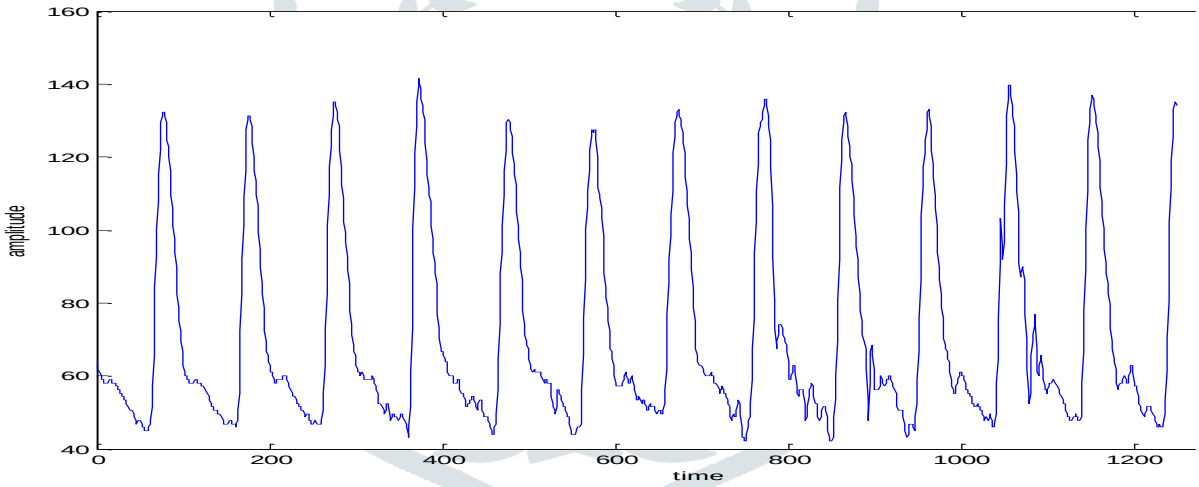

Fig.1.2 Blood Pressure Signal

The next section describes the various techniques that have been proposed by different authors for the estimation of Blood Pressure.

II. LITERATURE SURVEY

Today extensive research is being done in the field of sensors and Internet of things. Internet of things is the basic principle involved in Wireless body area network. As the name suggests internet of things consist of interrelated devices that is an integration of mechanical device , computing device, animal, people or anything that has a unique identifier and can be connected over the network or internet without the human-human interaction or computer to human interaction. The automatic control of major home appliances like refrigerator, A.C., Washing Machine, lights, fans etc comes under the Internet of things.
There are various upcoming technologies in wireless sensor network of which the wireless body area network is one such technology. Wireless body area network revolves around various types of sensors that could be implanted on the skin or under skin for the monitoring purpose.

Among all the signals captured by the sensors of WBAN the blood pressure signal gives the vital information about the physiological variation, elasticity of blood vessel and cardiac output. Hence BP signal is an important signal that needs to be monitored. The various conventional methods that are used in the hospitals and daily monitoring of the blood pressure do exist but the change is the need of the hour.
Kleinman C.S. and Seri I. [1] has talked about the Oscillometric method which was proposed in the year 1876. In the method the oscillations in a BP monitor cuff are recorded during deflation. The recordings are the required BP measurement but it had few disadvantages such as it was not precise in case of arrhythmia patients and cost of device was high.

Simmers .L. [2] has written about the most commonly method that is used for BP measurement which is Mercury Sphygmomanometers. It was developed in the year 1896. The glass tube is dipped in a bowl of liquid mercury and graded in mm Hg.

Heyward H.V. and Gibson .A [3] has talked about the Automated Arm Sphygmomanometers which is a direct technique developed in year 1897.This is digital BP measurement method. The digital monitoring component is connected to an inflatable cuff worn around an electronic display. The electronic display shows the measured BP but is not accurate with patients with irregular heartbeats or arterial stiffness.

The Existing techniques are cuff based and the continuous BP measurement is invasive where a catheter is inserted into the blood vessel during the surgery or intensive care settings this method is painful ,causes discomfort to the patient ,may to lead to infection and a close supervision is needed after the catheter is removed. Apart from these direct techniques, there are some indirect, non invasive and cuffless techniques that take into account the Pulse Transit Time (PTT) for BP measurement. The delay between the times when blood leaves from aortic valve where it is ejected from the left ventricle of heart till the time it reaches the peripheral site is known as PTT.

Magavi et. Al.[4] has proposed a model for Estimation of Mean Arterial Pressure from ECG and BP. The ECG and BP (SBP, DBP) recordings are taken from the source data. The golay filter is used in removal of noise (low frequency components) from the ECG signals. The P, QRS , T peaks of ECG signal are extracted using MATLAB equations , then the PTT is calculated as the time period between the ECG R-peaks and the troughs, peaks and zeros of the SBP and DBP, respectively. The outlier removal was applied on the PTT measured and then the cuff pressure of the calculated PTT signal's maximum is determined. The detected maximum of PTT signal is the estimated MAP.

Sahoo et.al.[5] found an inversely proportional relationship between pulse transit time and blood pressure. Biokit was used to record ECG & PPG signals at a sample rate of 1000 samples/second. For removal of noise Discrete wavelet transform (DWT) is used .The signals were decomposed into 8 levels by daubechies 6 (db6) wavelet. The noise free signals and QRS Complex are obtained. Lastly the correlation was applied to know the type of relationship between the variables.

Estrada et.al.[6] found a relationship of Blood Pressure with pre-processed ECG signal. The peaks of R and T waves are indentified by applying the wavelet transforms. Two neural networks are used to distinguish between the portions of systole and diastole taken from the ECG signal. The training sample for the ANN consists of actual and calculated values of systole and diastole portion. After training the classifier was applied on the test signals. The results show and interrelationship between ECG and blood pressure.

III. PROPOSED WORK

In health care monitoring the main focus is on the blood pressure monitoring because it is the second largest leading cause of deaths. The literature survey depicts all types of measurement techniques such as direct and indirect techniques. All the indirect techniques mentioned takes into account two signals that are ECG signal and photoplethysmograph (PPG) signal using which a new parameter is calculated that the pulse transit time. Using this parameter the Blood Pressure is estimated. Though there are certain problems associated with two signals such as it becomes time consuming, calculations and signal preprocessing becomes complex. It requires calculation of a third parameter for the estimation that becomes a quite tiring task. Even the dataset that has to be taken for this purpose becomes quite large.

The proposed methodology aims to make a regression based technique that will help to estimate the blood pressure taking into account only one signal that is ECG Signal. The work will find the kind of relationship that exists between the ECG Signal and the blood pressure signal. The dataset has been extracted from the KAGGLE Database [7][8]. The files are read and plotted in MATLAB. As the acquisition of these signals is not noise free the signal preprocessing techniques are studied and the best of all the techniques are applied.

After the signal preprocessing the filtered signal is received. Now the major wave that is easily detectable in an ECG signal is the QRS complex. In the QRS complex, the R Peak which has the highest amplitude is required in the proposed work. This important R peak (the wave with the maximum amplitude) of the ECG signal is found using peak finder in MATLAB and finally the work uses correlation to find the relationship between the detected R peak (the wave in ECG signal with maximum amplitude) and the Arterial Blood Pressure .It further makes use of Regression analysis to estimate the blood pressure.

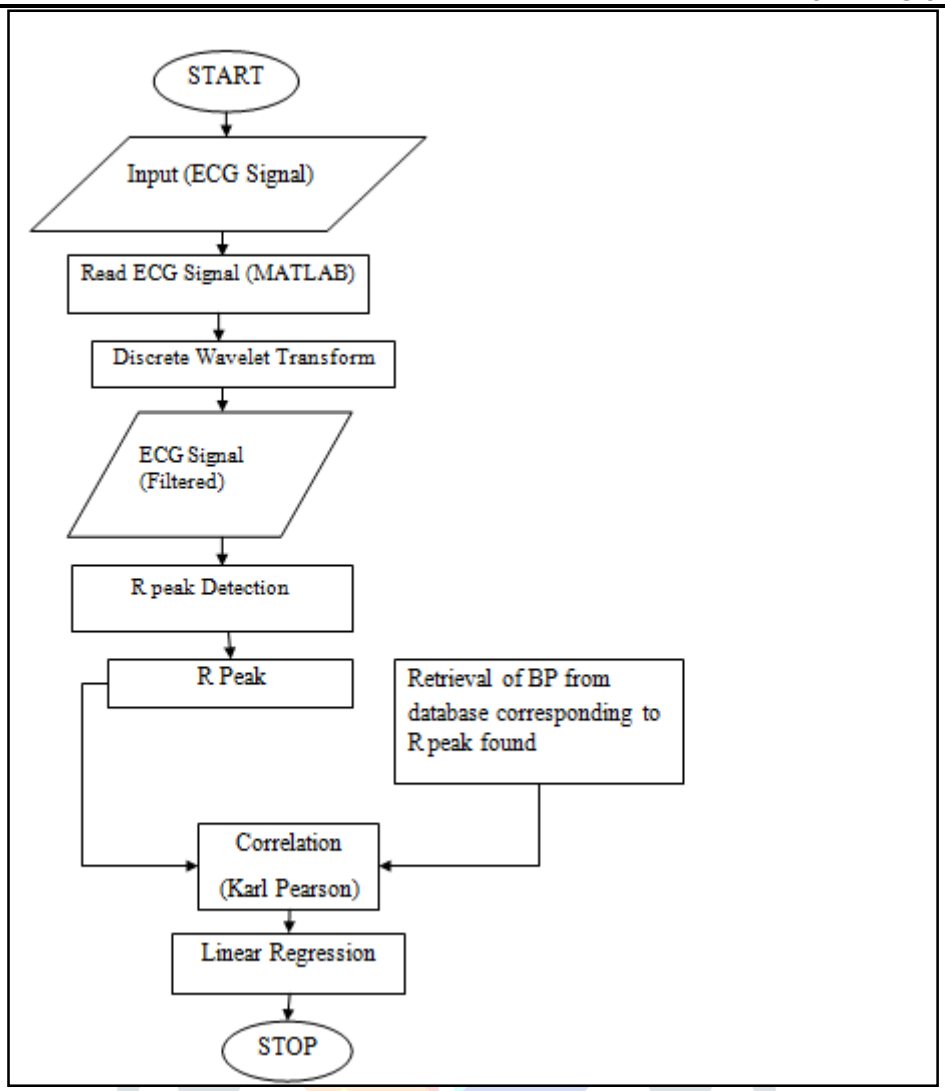

Fig. 3.1 Flow chart of Proposed Work

3.1 Signal Acquistion

The Electrocardiograph and Blood Pressure signals are extracted from KAGGLE Database as .mat file. Lead II is taken for experimental purpose. The signals thus extracted are loaded into MATLAB and the plotted signals are shown in Fig.3.2.

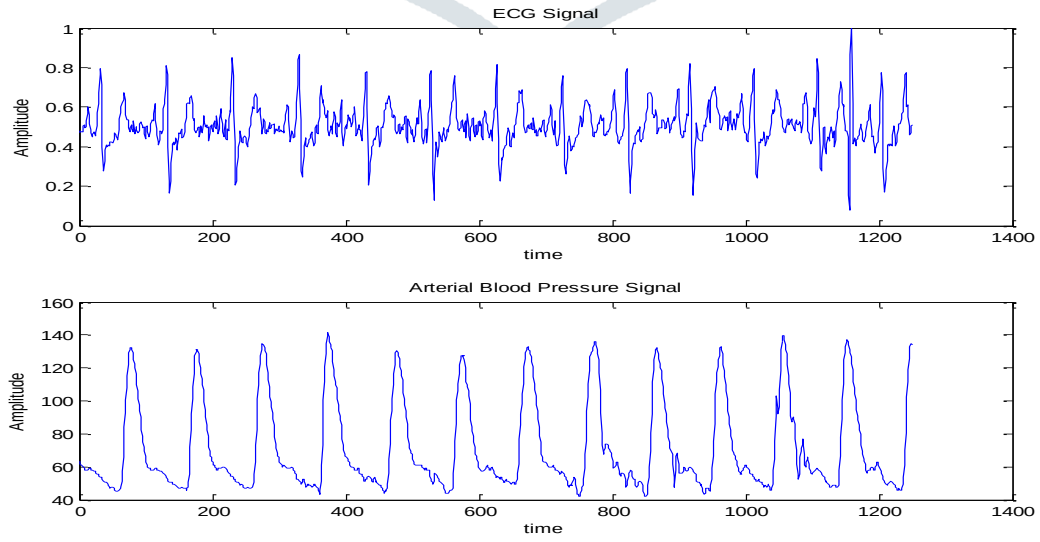

Fig. 3.2 ECG and Blood Pressure Plot in MATLAB

3.2 Signal Preprocessing

The ECG signals when recorded are affected by noise and artifacts. Hence there is a need to preprocess the ECG Signal to obtain the noise free signal and perform certain analysis on it. The preprocessing of the signals is done using the discrete wavelet transform with soft thresholding.

The Raw ECG signal is depicted in Fig.3.3.

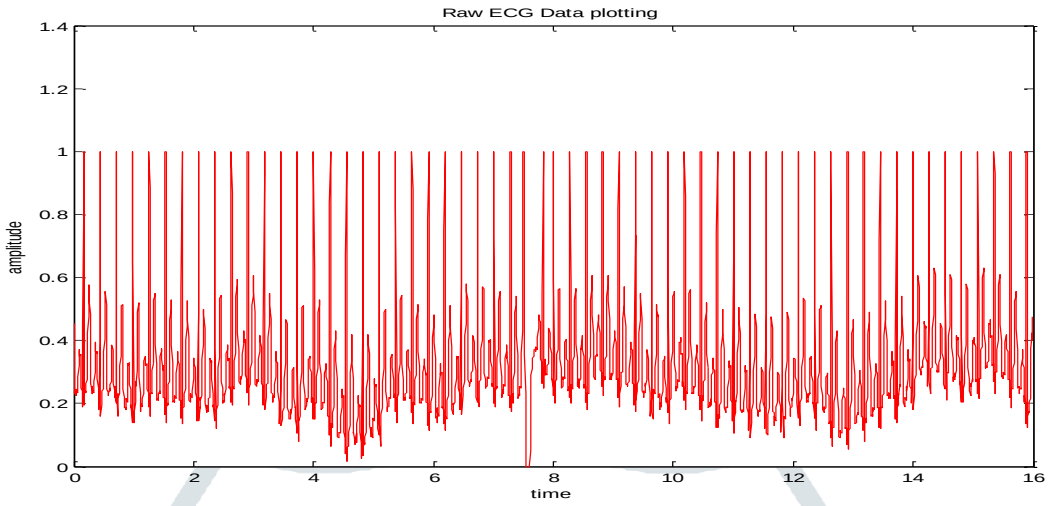

Fig. 3.3 Raw ECG Signal

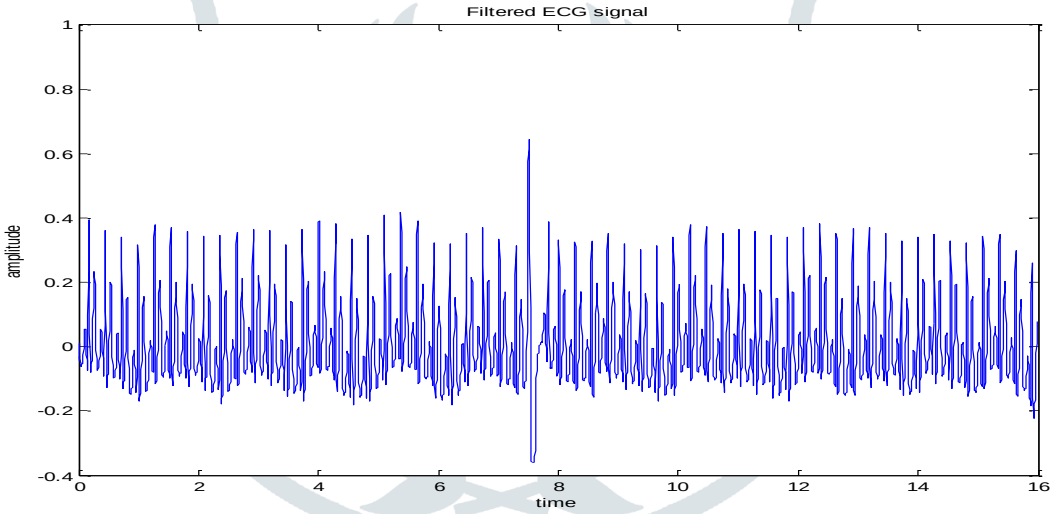

Fig. 3.4 Filtered ECG Signal

After the filtered signal is received the R peak of the ECG Signal is detected using peak finder in MATLAB. The detected R peaks are shown in fig.3.5.

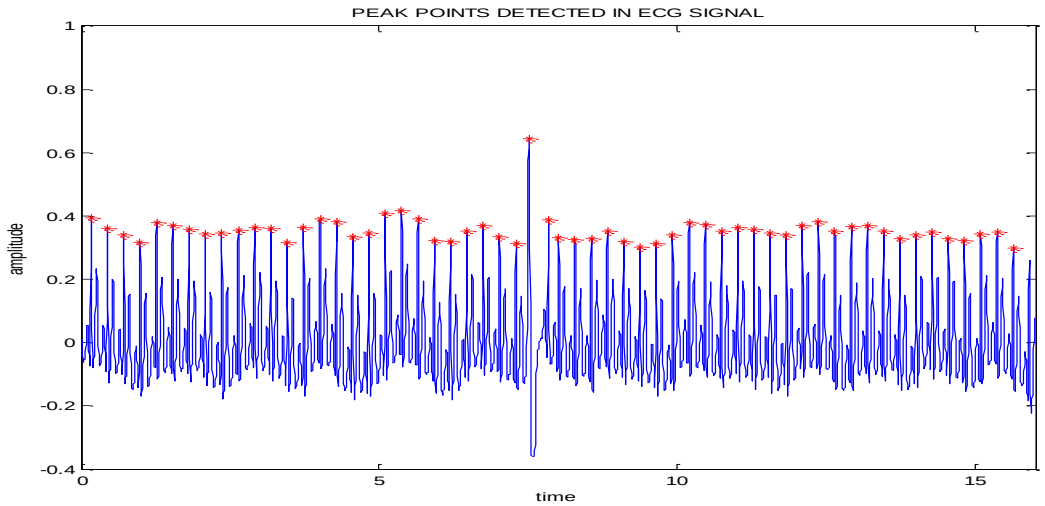

Fig. 3.5 R peak detected in filtered ECG Signal

3.3 Correlation

The strength as well as direction of the relationship between the two variables is found using correlation. The correlation values between the ECG R peak and the arterial blood pressure is calculated using the Karl Pearson Correlation of Coefficient. The formula is as follows:-

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2}\sqrt{\sum(y-\bar{y})^2}} \quad (1)$$

Where x is R peak value
y is arterial blood pressure value

Table 3.1 Degree of Correlation

S.No.	Degree of Correlation	Positive Correlation	Negative Correlation
1.	High Degree of correlation	$0.75 \leq r < 1$	$-1 < r \leq -0.75$
2.	Moderate Degree of Correlation	$0.50 \leq r < 0.75$	$-0.75 < r \leq -0.50$
3.	Low Degree of Correlation	$0 < r < 0.50$	$-0.50 < r < 0$
4.	Absence of Correlation	0	0
5.	Perfect Correlation	+1	-1

3.4 Linear Regression

Linear Regression analysis is a powerful statistical method that examines the relationship between two variables. For estimating the blood pressure the linear regression is applied.

Let regression line y on x is

$y = p2 + p1x$ (2)

Where y is blood pressure and x is the ECG R peak.

Normal Equations are

$\sum y = Np2 + p1\sum x$ (3)

$\sum xy = p2\sum x + p1\sum x^2$ (4)

Solving (3) and (4), we get values of p1 and p2.

Putting the values of p1 and p2 in (2) we get $y_c = p2 + p1x$.

IV. RESULTS AND DISCUSSION

The fig. 4.1 shows the line obtained when the linear regression was applied on the data set points.

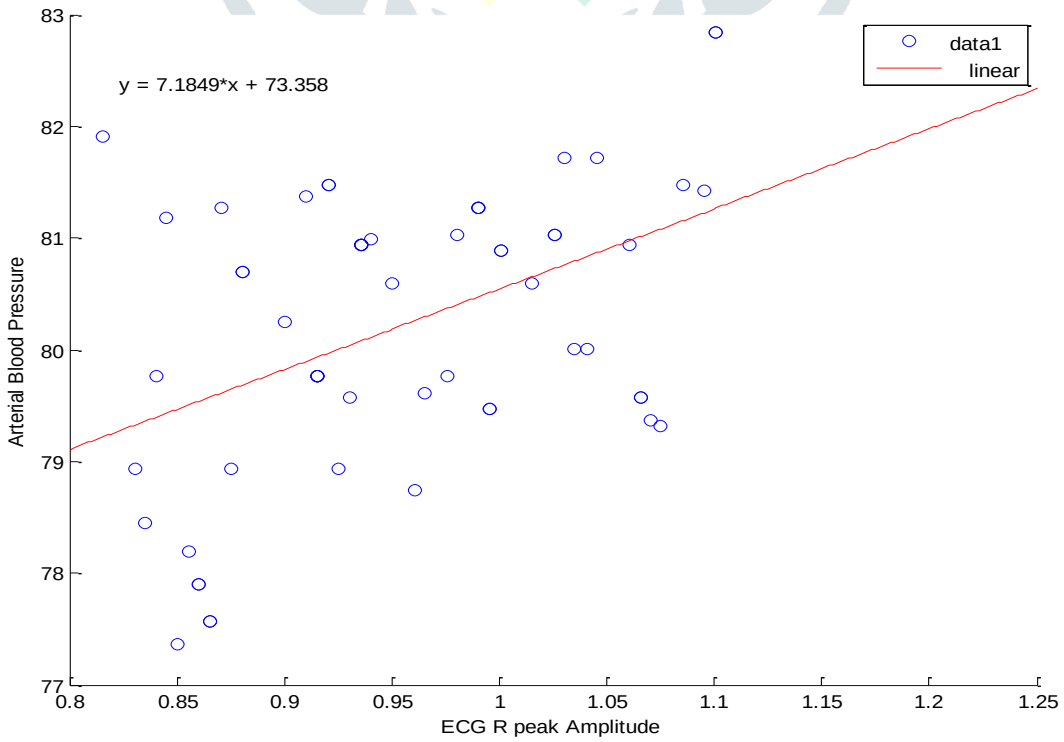

Fig. 4.1 Linear Regression Line

Table 4.1 Goodness of Fit

Coefficients	p1 = 7.185 (3.367, 11) p2 = 73.36 (69.7, 77.02)
SSE	74.69
R-square	0.2025
Adjusted R-square	0.1882
RMSE	1.155

Table 4.2 Estimated BP values & Error Calculation

ACTUAL ABP ('mmHg')	ESTIMATED ABP ('mmHg')	ERROR VALUE = ACTUAL ABP – ESTIMATED ABP
79.225	79	0.225
80.119	79.7	0.419
80.6255	79.8	0.8255
78.73	80.3	-1.57
80.588	80.5	0.088
82.10	80.7	1.4
81.0323	80.7	0.3323
79.345	81.1	-1.755
81.423	81.2	0.223
81.448	81.3	0.148

The total percentage of error is calculated using the formula given below:-

$$\%err = \frac{\sum|actual - estimated|}{\sum actual} \times 100 \quad (5)$$

% Error calculated = 1.069

V. CONCLUSION AND FUTURE WORK

The correlation value is 0.45 that shows there is a low degree of positive correlation between the two variables that is the ECG R peak and the arterial blood pressure. Linear regression analysis was applied to estimate the blood pressure. Table III depicts the estimated values of blood pressure and the total percentage error value comes out to be 1.069. The work proves that there exists a relationship between the ECG and Arterial blood pressure. The future work involves improving the accuracy of results using other statistical tools. The author also aims to acquire the signals using the ECG Module such as AD 8232 Module and make a real time processing system.

REFERENCES

[1] C.S.Kleinman and I.Seri, "Hemodynamics and Cardiology: Neonatology Questions and Controversies", Second Edition, Elsevier Health Sciences, 2012, p.53

[2] L.Simmers, "Introduction to Health Science Technology", Second Edition, Cengage Learning, p.429

[3] H.V.Heyward and A.Gibson,"Advanced Fitness Assessment and Exercise Prescription", Seventh Edition, Human Kinetics, 2014, p.36

[4] R.R. Magavi, Rayeesabanu.I.Jinabade, " Estimation of Mean Arterial Pressure from ECG and BP using Mathematical Model " , International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 5, Issue 4, April 2016

[5] Ashima Sahoo, P.Manimegalai , Dr.K.Thanushkodi, " Wavelet Based Pulse Rate And Blood Pressure Estimation System From ECG And PPG Signals" , International Conference on Computer, Communication and Electrical Technology – ICCCET2011, 18th & 19th March, 2011.

[6] Gendy Monroy Estrada , Luis Enrique Mendoza , Valentin Molina ," Relationship of blood pressure with the electrical signal of the heart using signal processing".

[7] M. Kachuee, M. M. Kiani, H. Mohammadzade, M. Shabany, Cuff-Less High-Accuracy Calibration-Free Blood Pressure Estimation Using Pulse Transit Time, IEEE International Symposium on Circuits and Systems (ISCAS'15), 2015.

[8] M. Kachuee, M. M. Kiani, H. Mohammadzadeh, M. Shabany, Cuff-Less Blood Pressure Estimation Algorithms for Continuous Health-Care Monitoring, IEEE Transactions on Biomedical Engineering, 2016.

[9] F.S. Cattivelli and H. Garudadri "Noninvasive Cuffless Estimation of Blood Pressure from Pulse Arrival Time and Heart Rate with Adaptive Calibration," Sixth International Workshop on Wearable and Implantable Body Sensor Networks, IEEE, Berkeley, CA , 3-5 June 2009, pp.114 -119

[10] B.Norrving, "Oxford Textbook of Stroke and Cerebrovascular Disease", Oxford University Press, 2014, p.257

[11] G.Baura,"Medical Device Technologies: A Systems Based Overview Using Engineering Standards", Academic Press series in biomedical engineering, Academic Press, 2011, p. 151

[12] A.G.Perry, P.A.Potter, W.Ostendorf, "Clinical Nursing Skills and Techniques8: Clinical Nursing Skills and Techniques": Elsevier - Health Sciences Division, Eighth Edition, 2013

[13] Xiaochuan He, Rafik A. Goubran, Fellow, IEEE, and Xiaoping P. Liu, Senior Member, IEEE, "Secondary Peak Detection of PPG Signal for Continuous Cuffless Arterial Blood Pressure Measurement", IEEE Transactions On Instrumentation And Measurement, Vol. 63, No. 6, June 2014

[14] Myint. CZ -IEEE Member, King Hann Lim, IEEE Member, and Kiing lng Wong, IEEE Member, Alpha Agape Gopalai, IEEE Member, Min Zin Oo , " Blood Pressure Measurement from Photo-plethysmography to Pulse Transit Time" , 2014 IEEE Conference on Biomedical Engineering and Sciences, 8 - 10 December 2014, Miri, Sarawak, Malaysia

[15]Hsu Myat Thwe, Hla Myo Tun (June 2015) , Patient Health Monitoring Using Wireless Body Area Network , International Journal Of Scientific & Technology Research Volume 4, Issue 06.

[16] Negra Remi , Jemili Imen , Belghith Abdelfettah (2016), Wireless Body Area Networks: Applications and technologies , The Second International Workshop on Recent Advances on Machine-to-Machine Communications , Procedia Computer Science 83 1274 – 1281.

[17] Samaher Al-Janabi , Ibrahim Al-Shourbaji , Mohammad Shojafar , Shahaboddin Shamshirb (2017), Survey of main challenges (security and privacy) in wireless body area networks for healthcare applications , Egyptian Informatics Journal 18 (2017) 113–122.