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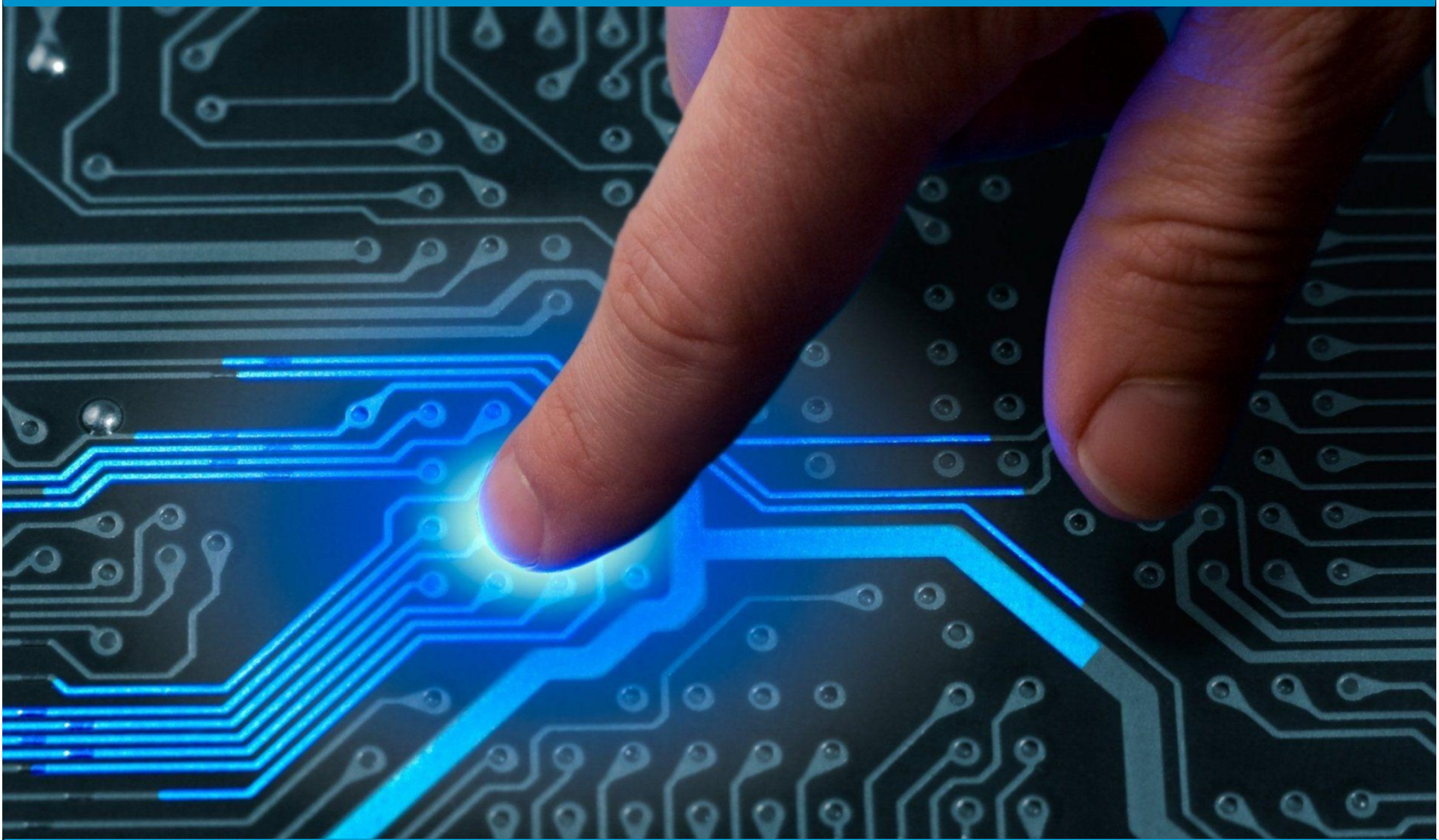

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Development of Non-invasive Diagnostic Tool for Diseases using Photo Plethysmography

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ABSTRACT: Heart rate and blood pressure are two vital signs used to measure basic functions of human body. Heart rate is the number of times heart beats per minute whereas blood pressure is defined as the pressure against the inner walls of the blood vessels. Blood Pressure (BP) is considered to be a strong indicator of an individual's well-being and one of the most important physiological parameters that reflect the functional status of the cardiovascular system of human beings. Although some smartphone applications can calculate heart rate, neither of these applications is capable of measuring or estimating blood pressure for their underlying sensor limitations. One of the fundamental characteristics of the heart is to be able to change its heartbeat rate. These spontaneous fluctuations of the heart rate (HR) reflect the relationship between ongoing interferences in the cardiovascular system and the response of its regulatory mechanisms.One of the methods used to evaluate cardiovascular autonomic nervous system activity is HRV analysis (cranial heart rate variability). The autonomic nervous system is responsible for the connection of the central nervous system to the cardiovascular system. The heart rate variability is constantly modulated through complex interactions between branches of the autonomic nervous system, the sympathetic nervous system, and the vagusnerve.Heart Rate Variability (HRV) is an important tool for the analysis of a patient's physiological conditions, as well a method aiding the diagnosis of cardiopathies. Photoplethysmography (PPG) is an optical technique applied in the monitoring of the HRV and its adoption has been growing significantly, compared to the most commonly used method in medicine, Electrocardiography (ECG).

This thesis presents a novel approach to develop a non-invasive tool using PhotoPlethysmography (PPG). This non-invasive device uses infrared light to capture the volumetric change of blood during each cardiac cycle as a PPG signal. Theoretically, any body part can be used to measure heart rate through the sensor of the device, although fingertips and earlobes are commonly targeted. The constructed device measures heart rate with a very acceptable accuracy limit. The system is completely hardware based and designed using Raspberry Pi controller and heart-beat sensors.

KEYWORDS: Cardiovascular diseases, Electrocardiography (ECG), heart rate, Heart Rate Variability (HRV), Heart-beat sensor, Photo Plethysmography (PPG),Raspberry Pi controller.

I. INTRODUCTION

Distinct diseases can be diagnosed by invasive method and non-invasive method. Important invasive methods are angioplasty, endoscopy, coronary catheterization etc. These are time-consuming, expensive and impractical for most emergency department environments. The noninvasive methods are reliable, easy to use and having good compatibility.There are several non invasiveplethysmogram techniques for recording blood volume changes in any part of the body such as volume displacement, strain gauge, impedance and photo plethysmography. For quick assessment of blood flow in the limbs, air displacement plethysmograph, commercially available as pulse volume recorder is commonly employed. Volume displacement plethysmography and stain gauge plethysmography have a common limitation in accurate estimation of blood flow. In both these methods 3 to 4 levels of conversions are required to finally get the electrical signals, which are recordable while assuming that all the conversions are linear throughout the process.Secondly, the output of pulse volume recorder and strain gauge plethysmography is non-specific to blood. The most widely applied 24-hour monitoring technique is Electrocardiography (ECG). But in some scenarios ECG does not provide evaluation of the functioning of human heart. Simultaneous recording of ECG and of a signal that reflects central hemodynamic activity might solve this problem.Impendencecardiography (ICG)the method calls for placement of surface electrodes on the body surface of the subject, free environment from electrical noise and stringent requirement on the specifications of the instrument from the consideration of patient safety [1]. There is always a need for non ohmic method, which can give idea about the blood circulation quickly and easily. Considering the drawback of impedance plethysmography like cumbersome procedure, ohmic contact with the patient etc., Photo plethysmography (PPG) is developed for the study of blood circulation, which is described in this paper. Photo plethysmography (PPG), a simple method that allows for continuous, non-invasive determination and monitoring of heart rate, pulse transit time etc., in the intensive care units as well as for the assessment of peripheral blood flow and venous filling time in vascular laboratories. Photo plethysmography (PPG) is used to estimate the blood flow using light. Researchers from different domains of science have been working with PPG because of its advantages as non-invasive, inexpensive, and convenient diagnostic tool. Traditionally, it has been used to measure the oxygen saturation, blood pressure and for assessing autonomic functions. Recent studies emphasize the potential information embedded in the PPG waveform signal and require attention for its possible applications beyond pulse oximetry and heart-rate calculation. The current systems based on photo plethysmography signal are used mainly for heart rate and SPO2 measurement.

II. LITERATURE SURVEY

Gorecka.M et.al (2017) [1] presented a classified analysis of cardiovascular disease. The Patients involved were admitted to Intensive Care Unit (ICU) detected with Acute Cardiac Arrest syndrome. A deep analysis was carried out in ICU for over 4 years and the analysis concluded the following: a. 31 patients in ICU suffered from Acute Cardiac Syndrome b. Among them 71% survived and were alive for a 6-month period c. 65% patients had good physical functions and could lead a normal function after 6 months. d. The results indicated that early admission of patients to hospitals due to acute cardiac arrest could save their lives irrespective of their age and gender.

Sinha.S.S et.al (2016) [2] conducted a research in Acute Cardiac Arrest in adults and also found breaks in various random tests using data collected from Cochrane Library from 1995 to 2014 based on non-traumatic cardiac arrest in adults. The research analysed 92 Randomised Controlled Trails (RCT) with 64,309 patients. Among the trials, 81 trailed outside the hospital. The results indicated that 86 trials of roughly 95% couldn't succeed but survived for about 6 months. It was also found that treatments had significant gaps in the cardiac outcomes and also needed solutions for long term survival from acute cardiac arrest among the affected patients.

Harris.K.Karamasis et.al (2016) [3] identified the factors that are required to persist the effects of cardiac arrest in patients before they get affected. The research analysed practical circumstances like cardiogenic shock, myocardial infraction physical problems, percutaneous coronary intervention risk factors, coronary artery surgery, refractory unstable angina and many more. The results identified that there are limitations in identifying the occurrence of Acute Cardiac Arrest in human or there is no possibility to identify it manually.

Stevenson.J.E et.al (2016) [4] conducted a research to analyse and examine the vital symptoms that might raise the cardiac arrest in future for a particular patient. The analysis was carried out among patients in hospitals who suffered from cardiac arrest from 2007 to 2011 on 228 patients. The hospital had a capacity 372 beds that could help the researcher to identify the results more efficiently. The analysis was designed with early warning sign score adopted for each and every symptom associated with the human body. Finally, the reasons for patients getting affected was recorded and presented in electronic records. Dankiewicz et.al (2015) [5] examined the impact of early coronary angiography that occurs as a result of Acute Cardiac arrest and which can be utilised to help recover the affected patients bypassing the ST elevation treatment in hospitals. The research utilised few of the major aspects for identifying this outcome, like analysing the temperature administration needs for the future, as the outcome showed no difference between an affected and an unaffected patient between 33 and 36 degree Celsius.

Geri.G et.al (2015) [6] studied the characteristics of Acute Kidney Injury which occurs as a result of patients affected and treated with sudden cardiac arrest. An assessment was carried out to find the risk factors that were the major causes of this disorder of heart and association of kidney as an outcome of infection of heart. The methodology applied to this research included patients admitted in Paris hospitals between 2007 to 2012. The patients were tested one by one on weight, serum creatinine level and therapeutic hypothermia to check if the heart problem affected the kidney at any cause. The research defined three different stages for the kidney to get affected as an outcome of cardiac arrest post hospital. Out of 580 patients which accounted to 71% Male with medium age 59.3, the Stage 3 affected 280 cases which was 48% of total male population. The stage finally resulted in the mortality of the patients within 30 days. The result was verified with 95% CI and $p = 0.03$ which was highly appealing. After 30 days only 67 patients remained in normal stage without their kidneys being affected; rest were affected with kidney problems. Hence the research proved that Acute Cardiac Arrest proves to affect other major organs in course of time even after survival.

Mehra.S et.al (2015) [7] indicated the best options for heart patients who came out of hospital after treatment to get a complete recovery in future perspectives. To analyse this research, the responses were collected from 112 successive patients based on electro cardio graphic data and elevated serum troponin. Around 63% recovered after analysis. Among the people who survived after cardiac arrest, those who endured were younger and were classified based on their age and gender bias. The new viewpoints of previous heart attack condition are very less with young patients whereas it is moderate in case of aged patients. Hence it is identified from this research that cardiac arrest doesn't show any symptoms for occurrence regardful gender or age-based patients and its mortality rate is very high. It is also identified that patients suffering from hypothermia have a high mortality rate of 80% compared to other criteria with

20% mortality rates. The results also confirmed that patients who suffered from severe blood pressure without cardiac arrest have survived using simple angiographic techniques.

Nolan.J.P (2014) [8] found the incident levels and outcome levels of patients in United Kingdom affected with acute cardiac arrest. The research data was collected from 144 hospitals in UK with 22,628 patients aging from 16 and above to the maximum level. Patients were given shock treatments, defibrillation and other methods to normalise the heart rhythms. The results indicated that early admission of patients suffering from cardiac arrest could be helped them to recover soon but with a caution to face cardiac problems in future. It was also identified that more symptoms and risk factors have to be assessed for better results.

Hollenback.R.D et.al (2014) [9] insisted the importance of early prediction of Acute cardiac arrest to help increase the survival rate of patients. The research identified the status of out-patients survived from Acute cardiac Arrest for further treatment. The research conducted retrospective observational study of the patients to identify the following results: a) Over 269 patients survived cardiac arrest due to treatment of ventricular arrhythmia b) A percentage of 26% was found to have acute coronary occlusion in early stage whereas 29% were treated only at a later stage and couldn't survive. c) The results confirmed that early detection of such disorders and symptom-based identification has prevented the loss of life and has reduced the mortality rates to a greater extent.

Ezekiel.D.M et.al (2017) [10] created a non-linear Fuzzy Login Expert system (NFL) which can identify the feedback through quantitative techniques using a well-defined control system. The research used a human heuristic procedure to identify knowledge and then convert it into fuzzy sets for implementation in MATLAB. The logic developed would mimic the knowledge expert in a particular domain and would suggest the right decision for the problems. The research used special features in MATLAB like Graphical user interface (GUI), 2 Dimensional methods, error controls systems, robust knowledge creator with quantitative feedback theory aspects. Hence the research design is very user friendly and m-files are easy to execute and obtain results in a systematic manner.

III. SYSTEM BLOCK DIAGRAM

System Architecture:

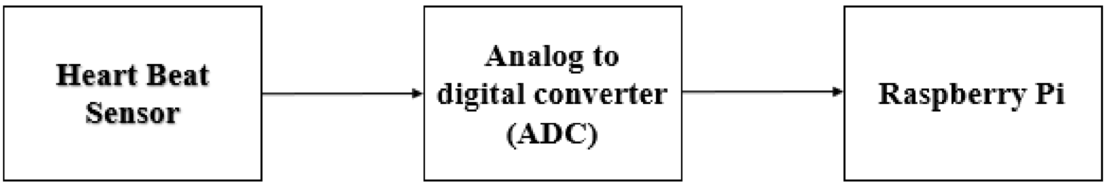

Fig 1: System architecture of the proposed system

The system is implemented using Raspberry Pi micro-controller along with a heart beat sensor. Heart beat sensor reads the signal and sends them to ADC unit. ADC converts these analog signals received from heart beat sensor to corresponding digital signals which are then ready to be transmitted to the Raspberry Pi. Once these input signals are processed by Raspberry Pi, wavelet transform is used. Output of wavelet transformer is given to the KNN classifier. KNN classifier is used to detect if there is any disease to the respective person whose signals are received from heart beat sensor.

Algorithm of the proposed system:

1. Design the required module and make the required connections.
2. Acquire input signal of user via heart beat sensor
3. Send input signal further to ADC unit for analog to digital conversion
4. Raspberry Pi reads this digitized signal from heart beat sensor
5. Compute wavelet transform of the input signal fed to Raspberry Pi.
6. For proposed KNN scheme, train the KNN module
7. Process the output signal of wavelet transformer to KNN classifier.
8. Any possible disease is predicted/detected via the KNN classifier.

IV. METHODOLOGY

Photo plethysmography (PPG) also referred to as photoelectric plethysmography (PTG), is a plethysmography technique of using sensors to detect the properties of the blood flow mainly in fingertip. PPG is a simple and low-cost optical technique that can be used to detect blood volume changes in the micro vascular bed of tissue. It is used non-invasively to make measurements at the skin surface. The basic form of PPG technology requires only a few optoelectronic components: a light source to illuminate the tissue (e.g. skin), and a photo detector to measure the small variations in light intensity associated with changes in perfusion in the catchment volume. Despite its simplicity the origins of the different components of the PPG signal are still not fully understood. It is generally accepted that they can provide valuable information about the cardiovascular system.

A diagnostic structure consists of three stages: Pre-processing, features extraction, diagnosis/classification. Preprocessing stage to emphasize the desired waves;Feature extraction stage to detect the desired waves; Calculate an index or a measure using the extracted features for classification and diagnosis.

System Block Diagram

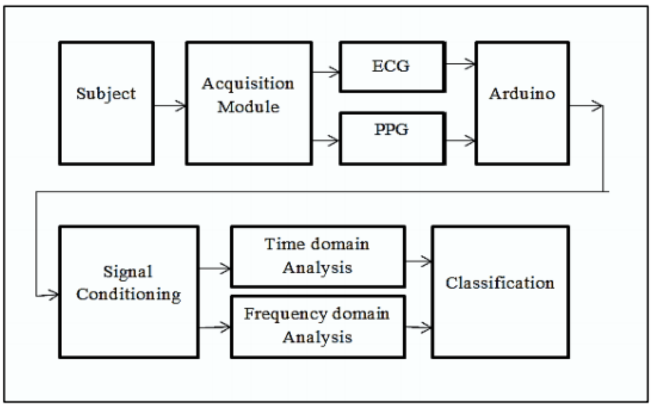

Fig 2 : System Block Diagram

Fig.2 shows the system block diagram for extraction and analysis of ECG and PPG Signals. PPG and ECG signals are collected from acquisition module are interfaced through Raspberry Pi board. The signals are visualised and recorded in LabVIEW VI and then further processed and conditioned in Python. The processed signal undergoes parameter extraction and are analysed in time as well as frequency domain. After analysis, classification of diseases carried out using multi variable regression. The subjects with or without ailments are discriminated on the basis of three indices. This classification is a preliminary diagnosis which can be used to determine which tests should be performed in earlier level.

Preprocessing

Preprocessing includes normalization, artifact removal and denoising. In case of a PPG signals, the major sources of artifacts are movement of the patient during acquisition. In the spectrums of the signal, fair amount of overlap if signal and artifact is present. Since, the acquisition of signals is done from the finger instead of the thorax; the amount of variation in the absorption with the blood flow is less, in turn makes the artifacts more dominant. Therefore, in order to maintain the temporal relations between the characteristic features of waveform for accurate diagnosis, selection of artifact removal algorithm is very crucial. The proposed system would use wavelet transform for removal of the artifacts. First, normalization process is used to standardize all features of the samples to the same level. Practical conditions like patient movements can cause shift in PPG signal baselines from zero line. This can be adjusted by subtracting the median of the signal. Unwanted contaminants such as noise have to be filtered from the PPG signal to get a proper output. These contaminants can be filtered using High pass filter, Low pass filter or wavelet transform (WT). WT based search algorithm isolates baseline wander from the PPG signal using the energy of the signal in different scales. The algorithm explained is based on the assumption that PPG signal and baseline drift constitute two independent signals mixed in linear manner. First step is to compute the wavelet transform of the signal. Next, Daub-8 mother wavelet is used for carrying out the dyadic wavelet packet decomposition of the PPG signal. Further, the energies of the signal for both the detailed & coarse levels are found out in each scale using the wavelet coefficients. As a next step of the algorithm, at each level the difference between energies of the coefficients at the current and the preceding level is calculated. Comparison of these energy levels is done and then the higher energy branch of binary tree is chosen. If energy differences threshold level of Eth is exceeded, then the path for higher energy branches is to be followed. This completes the binary tree search, and inverse wavelet transform of the last scale wavelet packet coefficient is taken to retrieve baseline wander signal. A PPG signal free from baseline wander is identified by subtracting estimated baseline drift from the original PPG data.

V. RESULTS AND CONCLUSION

Hardware uses raspberry pi along with analog to digital converter with heart beat sensor. Following picture illustrates the components connection of hardware.

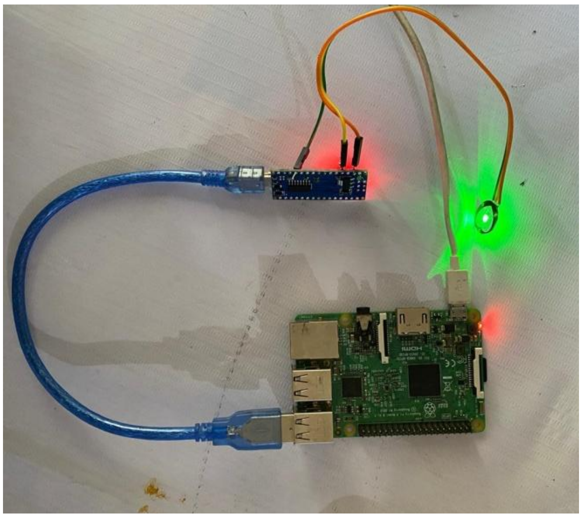

Fig. 3 Hardware Implementation

Database has been designed with the same sensor module which has been used for the testing purpose to maintain the accuracy.First values from the sensor are taken and those values are then passed through the wavelet transform with db3 filter. Statistical analysis of filtered values are compiled in excel sheet to generate database. Example of the database is as shown in following figure.

A	B	C	D	E	F	G
STD	VAR	MEAN	MEDIAN	MIN_VAL	MAX_VAL	DISEASE
55.45933806	3075.738178	329.2816014	304.0559159	282.5351231	532.5190007	Healthy
2.386064377	5.693303213	724.9589258	724.1275589	721.3383423	731.2592009	Healthy
9.242183178	85.4179499	726.516267	725.4563312	683.4275949	777.3514363	Healthy
0.26262545	0.068972127	725.4279553	725.4915575	723.9775592	726.6311196	Healthy
6.98309482	48.76361326	725.4169971	725.4915575	690.7645361	776.1138092	Healthy
5.023877846	25.23934861	724.5001097	722.683368	717.138732	736.9734548	Healthy
2.987858979	8.927301278	724.2767413	723.6592321	719.7844883	732.7236295	Healthy
2.061897234	4.251420205	724.3192696	723.9298994	721.0636908	732.6153955	Healthy
2.891010766	8.357943251	726.1648061	725.4915575	712.7272831	738.2748049	Healthy
450.234	500.234	5.342343242	5.23432234	60.324234	164.5235	Diabetic
452.4234234	534.234	5.324234324	6.23432234	61.324234	164.4355235	Diabetic
451.234	500.234	5.453432423	5.992234	64.24234	159.4355235	Diabetic
452.2971411	511.5673333	5.484425844	6.578204553	65.88170867	157.7102058	Diabetic
452.7971411	511.5673333	5.539970435	6.957160383	67.84076167	155.1662176	Diabetic
453.2971411	534.5673333	5.595515025	7.336116213	69.79981467	152.6222293	Diabetic
453.7971411	511.5673333	5.651059616	7.715072043	71.75886767	150.0782411	Diabetic
454.2971411	512.5673333	5.706604207	8.094027873	73.71792067	147.5342528	Diabetic
454.7971411	511.5673333	5.762148797	8.472983703	75.67697367	144.9902646	Diabetic
712.345232	753.324	72.5234	50.2421	100.25324	154.2324	Heart_disease
711.124	751.9345535	71.23423423	52.23342342	99.23412241	152.3243434	Heart_disease
709.902768	750.5451069	69.94506847	54.22474685	98.21500482	150.4162868	Heart_disease
708.681536	749.1556604	68.6559027	56.21607027	97.19588724	148.5082302	Heart_disease
707.460304	747.7662138	67.36673694	58.20739369	96.17676965	146.6001736	Heart_disease
706.239072	746.3767673	66.07757117	60.19871712	95.15765206	144.692117	Heart_disease

Fig. 4 Database for disease classification

Classification of disease is done by using Machine learning algorithm KNN is used for the same.
Some results are as shown below so that one can easily understand system visually.

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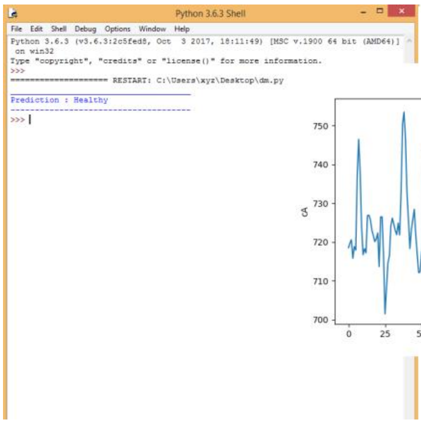

Fig. 5 Prediction and graph of heart beat of healthy person

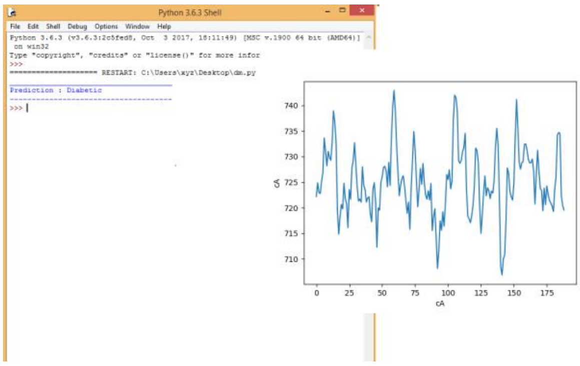

Fig. 6 Prediction and graph of heart beat of Diabetic

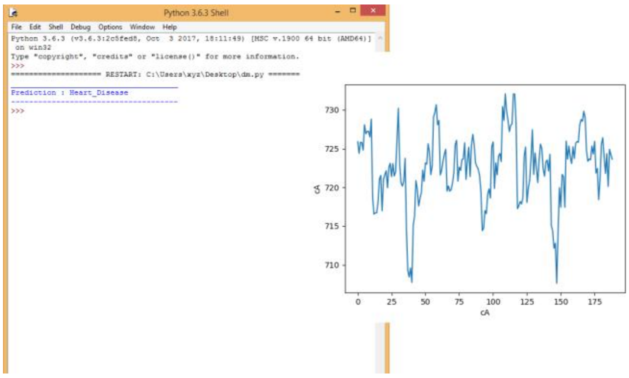

Fig. 7 Prediction and graph of heart beat of Heart Disease

VII. CONCLUSION

In Biomedical measurement, there are very few reliable and suitable non-invasive methods (ECG) for measuring and monitoring cardiac flow in clinical practice. Photo plethysmography method is able to further enhance this reliability.Distinct diseases can be diagnosed by invasive method and non-invasive method. Important invasive methods are angioplasty, endoscopy, coronary catheterization etc. These are time-consuming, expensive and impractical for most emergency department environments. The noninvasive methods are reliable, easy to use and having good compatibility.There are several non-invasive plethysmogram techniques for recording blood volume changes in any part of the body such as volume displacement, strain gauge, impedance and photo plethysmography.

This thesis proposes a system to develop non-invasive diagnostic tool for disease prediction using Photo plethysmography. The system is implemented using Heart beat sensor and Raspberry Pi. Python software is used to implement the required code to be executed. KNN classifier is used to classify and detect the possibility of disease if any, in the input signal. It is observed that the designed system is capable of giving accurate and efficient results i.e. the system accurately detects any disease possibility in the input signal.

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