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ARRHYTHMIA DETECTION FROM PPG SIGNALS

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Abstract— **These days, sudden cardiac arrest is the leading cause of death worldwide,affecting a large number of people.Cardiac arrhythmias can be diagnosed with Electrocardiogram (ECG). No one will have ECG machines in home and it also requires the electrodes to stick at appropriate places and will take time to analyze the ECG. Meanwhile, after the COVID pandemic, most of people are using finger pulse oximeter to check their vitals. Since there is a correlation between Electrocardiogram (ECG) and plethsymogram(PPG), it can be used to detect serious arrhythmias. A wearable finger pulse oximeter uses spectrophotometry and plethysmography to determine the oxygen saturation level and pulse rate. My objective is to build a wearable finger pulse oximeter with an MAX30102 pulse oximeter sensor and Arduino microcontroller that detects major cardiac arrhythmias with the help of the signal processing tool Neurokit. With the help of this project, I hope arrhythmias can be detected early and save lives with proper treatment.**

Keywords— **Sudden Cardiac Arrest, ECG, PPG, Pulse oximeter, Arrhythmia analysis, Arduino application, Neurokit.**

I. INTRODUCTION

Blood volume changes in microvascular bed of tissues can be detected by an optical measurement technique called as Photoplethysmography (PPG). It consists of a light source (RED & IR) to illuminate the tissue and a photodetector to detect the small variations in light intensity, which corresponds to changes in perfusion [1].The voltage from PPG is proportional to the quantity of blood flowing through blood vessels.

PPG shows blood flow changes with a graph. The graph has an Alternating current (AC) component and a Direct current (DC) component. The AC component corresponds to variations in blood volume in synchronous with heartbeat. The DC component relates to tissues and average blood volume with the sample. The AC component is superimposed on the quasi-DC component. The DC component varies due to respiration, vasomotor activity and vasoconstrictor waves. The appearance of the pulse was defined as two phases: the **anacrotic phase** being the rising edge of the pulse, and the **catacrotic phase** being the falling edge of the pulse. The first phase is primarily concerned with systole and the second phase with diastole and wave reflections from the periphery. A dicrotic notch is usually seen in the catacrotic phase of subjects with healthy compliant arteries[1].

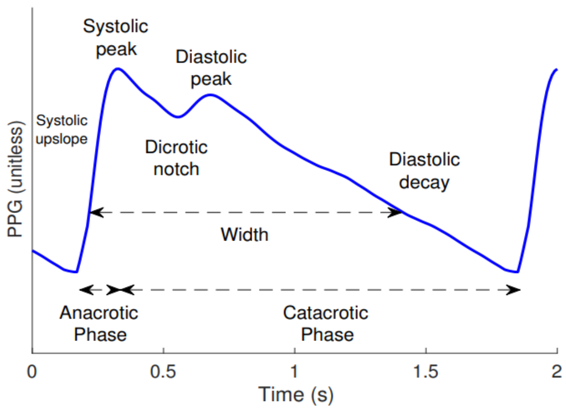

Fig.1. Typical Plethysmogram wave [4].

The waveform can be separated into anacrotic and catacrotic phases, which are dominated by systolic ejection and wave reflections from the periphery respectively. The systolic rising edge in the anacrotic phase is caused by the expansion of the arterial system due to the inflow of blood. The rate of expansion is linked to the contractility of the heart, and the amplitude of the systolic peak is linked to the stroke volume. The dicrotic notch and diastolic peaks are caused by wave reflections, with their location and timing influenced by arterial stiffness. The diastolic decay is determined by the exponential contraction of the arterial system due to the outflow of blood, and is influenced by vascular resistance and compliance[4].

SpO2 can be determined by shining red (660nm) and then near-infrared (940nm) light through vascular tissue, with rapid switching between the wavelengths. The amplitudes of the red and near-infrared AC signals are sensitive to changes in SpO2 because of the differences in the light absorption of HbO2(Oxyhemoglobin) and Hb(hemoglobin) at these two wavelengths. From their amplitude ratio, and corresponding PPG DC components, SpO2 can be estimated [1].The PPG wave can be used as a tool to detecting and diagnosing cardiac arrhythmias. The beat-to-beat variation in PPG amplitude may be a clue that the patient has developed an irregular rhythm. The sudden reduction in the amplitude of the pulse oximeter waveform, combined with the typical ECG pattern, should give an important warning regarding the presence of a dangerous situation [3].

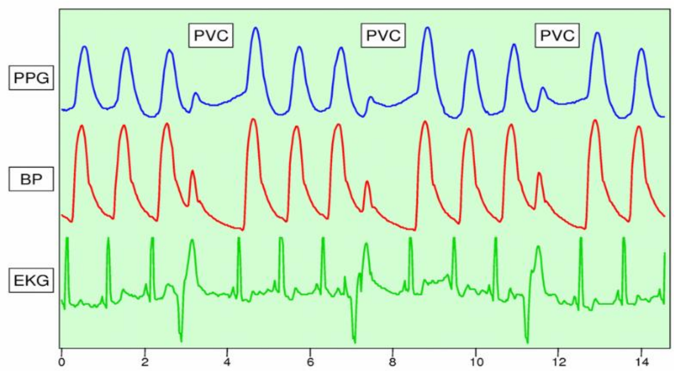

Fig.2.1 Impact of Premature Ventricular complex on ECG, Blood Pressure and PPG[3].

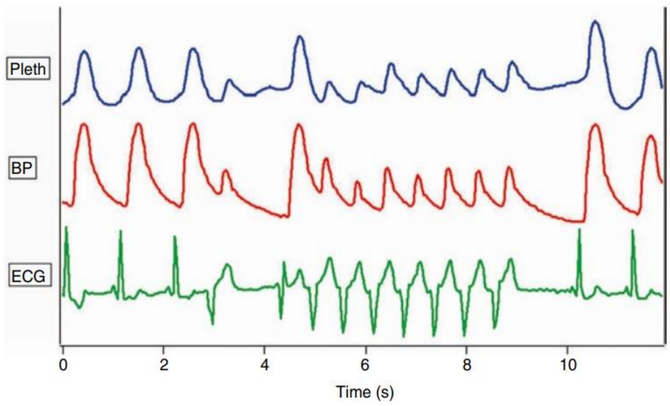

Fig.2.2. Impact of Ventricular Tachycardia on ECG, Blood Pressure and PPG [3].

NeuroKit2 is an open-source, community-driven, and user-centered Python package for neurophysiological signal processing. It provides a comprehensive suite of processing routines for a variety of bodily signals (e.g., ECG, PPG, EDA,
EMG, RSP).

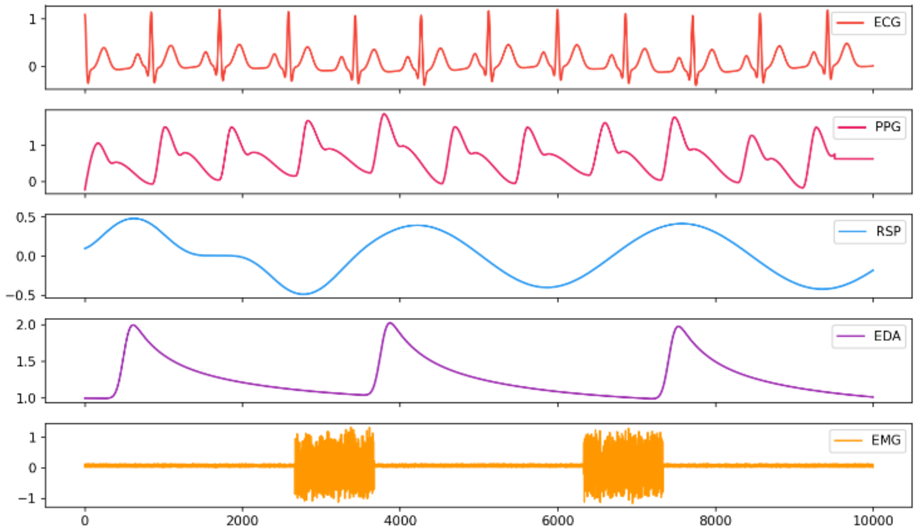

Fig.3. Overview of physiological signals in Neurokit2[5].

The package also includes tools for specific processing steps such as rate extraction and filtering methods, offering a trade-off between high-level convenience and fine-tuned control. NeuroKit2 offers a breadth of functionalities that includes, but is not limited to, signal simulation; data management (e.g., downloading existing datasets, reading and formatting files into a data frame); event extraction from signals; epoch extraction, signal processing (e.g., filtering, resampling, rate computation using different published algorithms detailed in the package's documentation); spectral analyses; complexity and entropy analyses; and convenient statistical methods (e.g., K-means clustering, ICA or PCA). A variety of plotting functions allow for quick and expressive visualization of the signal processing and the resulting features[5].

II. MATERIALS AND METHODS

To detect cardiac arrhythmias, Electrocardiogram (ECG) is used. To take a ECG test we must go to a nearby hospital or clinic or we should have a ECG machine at home which is very costly. In contrast a pulse oximeter is very affordable and it gives Oxygen saturation and heart rate as output. As discussed earlier, since the PPG is synchronous with ECG it can be used as a diagnostic tool for arrhythmia analysis.

A. Materials Used:

i. Sensor Selection:

In order to get the SPO2 and Heart rate, we need a sensor to record the plethysmogram. Photo Plethysmogram is a technique in which RED(660nm) and IR(940nm) light is illuminated on the tissue. Some of the light particles (photons) are scattered, reflected, and absorbed. A photodetector detects the light after passing through the tissue. Those photons that reach the photo detector has undergone scattering and absorption. Thereby, by measuring the change in intensities of detected light, relative change within the tissue can be determined [6].

MAX30102 monitors heartbeat per minute and plays a crucial role in measuring blood oxygen saturation (SPO2). MAX30102's ambient light filtering capabilities enhance data accuracy, ensuring reliable performance even in challenging environments. Overall, the combination of accuracy, efficiency, and versatility makes the biosensor an outstanding choice for real-time patient monitoring[7].

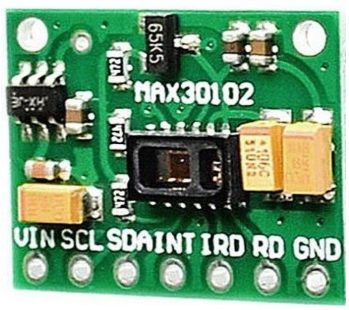

Fig.4. MAX30102 sensor

Courtesy:
(https://www.indiamart.com/proddetail/max30102-pulse-oximeter-heart-rate-sensor-module-i2c-2850023703097.html)

Specifications:

- LED peak wavelength: 660nm/880nm.
- LED power supply voltage: 3.3~5V.
- Detection signal type: light reflection signal (PPG).
- Output signal interface: I2C interface.
- Operating Temperature Range: -40°C to +85°C

- Dimension: 20.3 x 15.2mm

ii. Microcontroller:

Arduino UNO is a microcontroller based on ATmega328p. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. It can be simply connected to a computer with a USB cable or powered with an AC-to-DC adapter or battery to get started. Arduino programs are written in the Arduino Integrated Development Environment (IDE). Arduino IDE is a special software running on the system that allows the user to write sketches (synonym for program in Arduino language) for different Arduino boards [8].

iii. Signal Processing tool:

NeuroKit2 is used as a Signal processing tool in this project.
The NeuroKit2 is an open-source, community-driven, and user-centered Python package for neurophysiological signal processing. It provides a comprehensive suite of processing routines for a variety of bodily signals (e.g., ECG, PPG, EDA,
EMG, RSP) [5].Neurokit2 analyzes the signal data Frame (2-D data structure). The data containing the signals are preprocessed and analyzed by inbuilt functions.

B. Proposed Method:

The MAX30102 Pulse oximeter sensor, integrated with an Arduino microcontroller, is utilized to capture PPG signals. The MAX30102 sensor raw data can be viewed ona serial monitor in Arduino IDE. With a little coding, SPO2 and Heart rate can be calculated. These data were collected with timestamps and saved as CSV files and updated every 30 seconds. The data in the CSV file were then used for analysis. The data contained within the CSV file undergoes preprocessing utilizing functions from the Neurokit2 library. The PPG signal is analyzed with the PPG analyze function. PPG_clean function aids in refining the signal by eliminating noise. In order to detect the arrhythmia, the peaks of the PPG wave have to be found. PPG_peaks function helps in finding peaks. Following peak detection, the algorithm assesses the rhythmicity of the signal, triggering an alarm if any irregularities in the rhythm are detected.

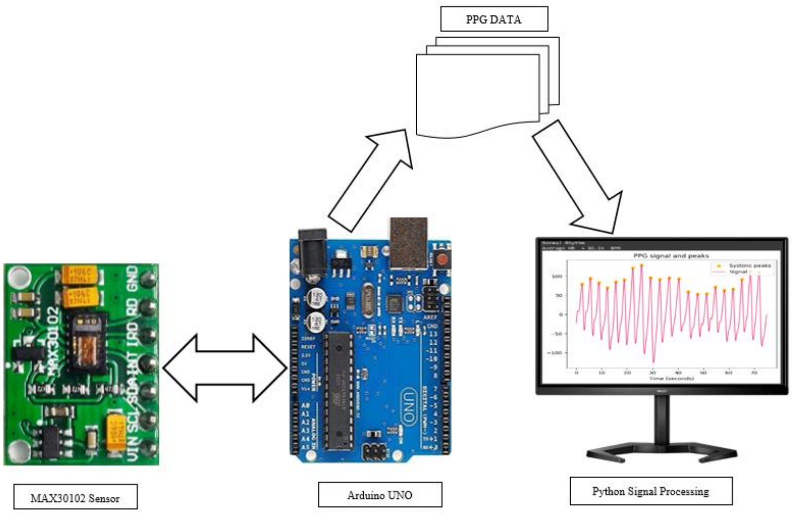

Fig.5. Overview of Proposed system.

III. EXPERIMENTS AND RESULTS

Various data were tested and trained in the system. The normal PPG data were collected from normal subjects. The atrial fibrillation PPG data were collected from the MIMIC PERform AF database [9].

The following outputs are shown in the below figures.
Fig 6.1.a is extracted from the non-atrial Fibrillation normal subject for 30 seconds. Fig 6.1.b is the resultant output of the data.

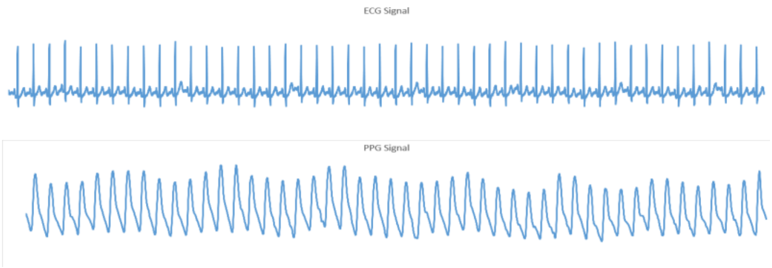

Fig. 6.1.a. ECG and PPG of Normal subject-1.

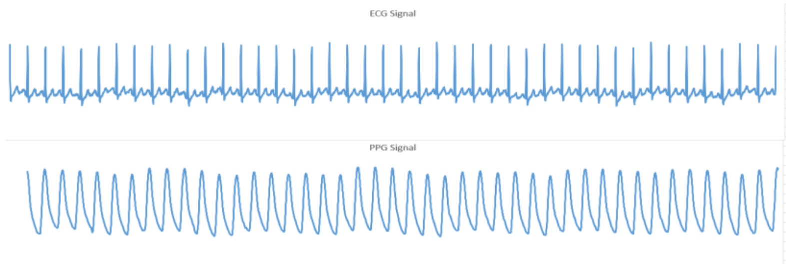

Fig. 6.2.a. ECG and PPG of Normal Subject-2.

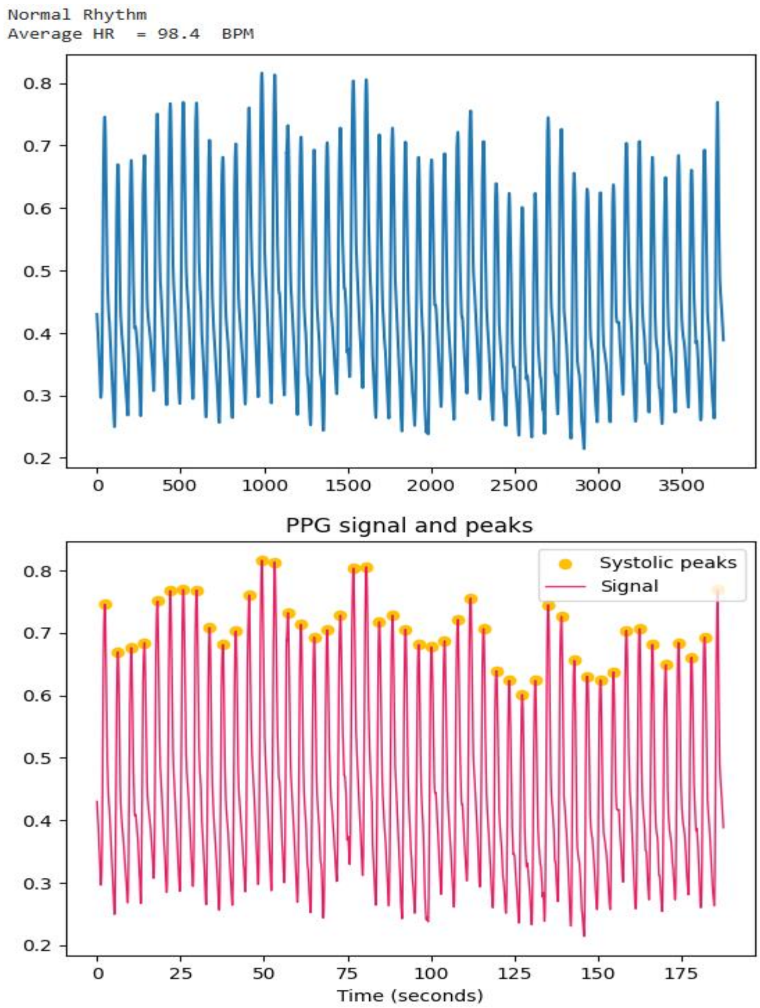

Fig. 6.1.b. Resultant output with Average HR for Normal Subject-1.

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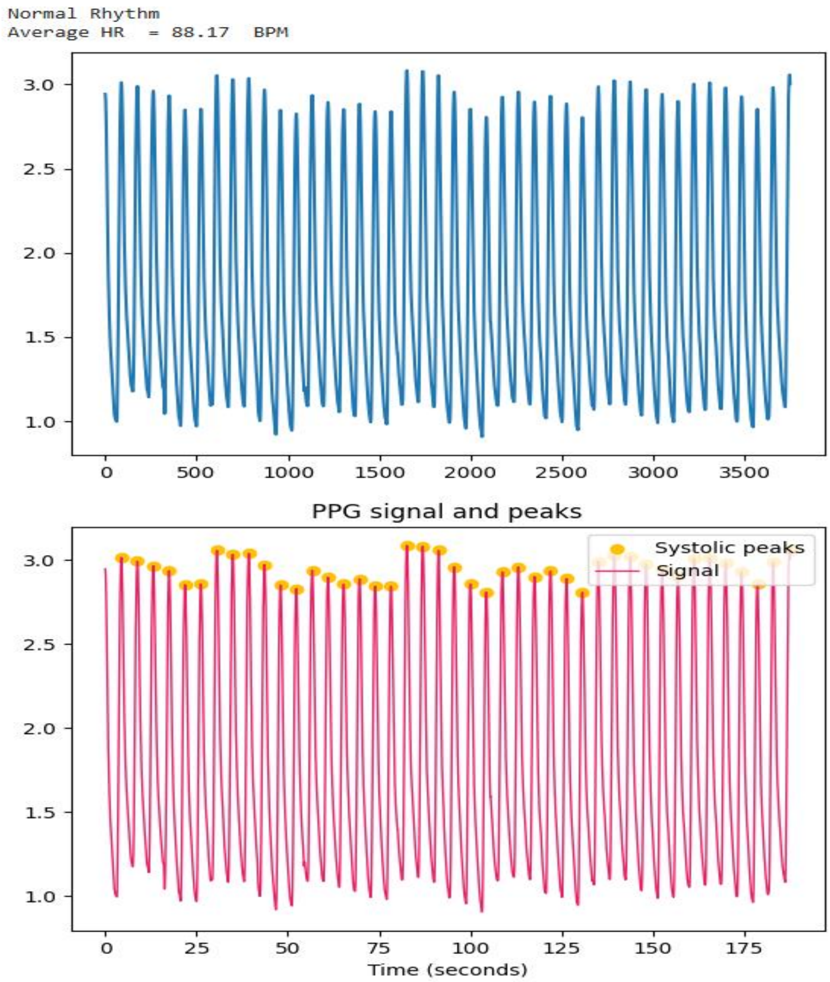

Fig. 6.2.b. Resultant output with Average HR for Normal Subject-2.

On the top of the output images, the rhythm is shown as normal or irregular rhythm. The average heart rate is also calculated for the 15 seconds. Figure 6.1.a. and 6.2.a. were the 15 seconds data of normal subjects. The resultant output graphs and average heart rate were shown in figure 6.1.b. and 6.2.b. respectively.

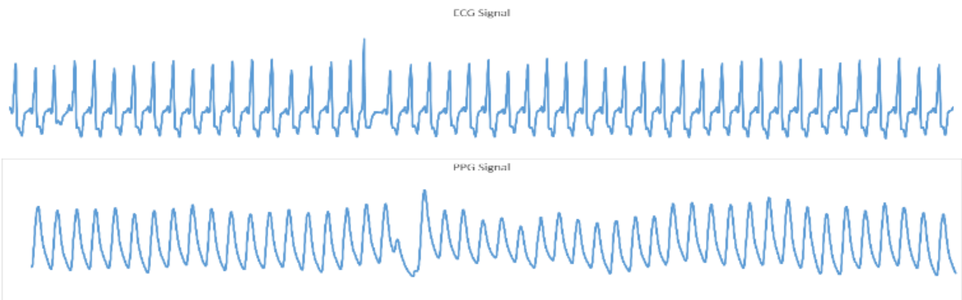

Fig.6.3. a. ECG and PPG with an Ectopic beat.

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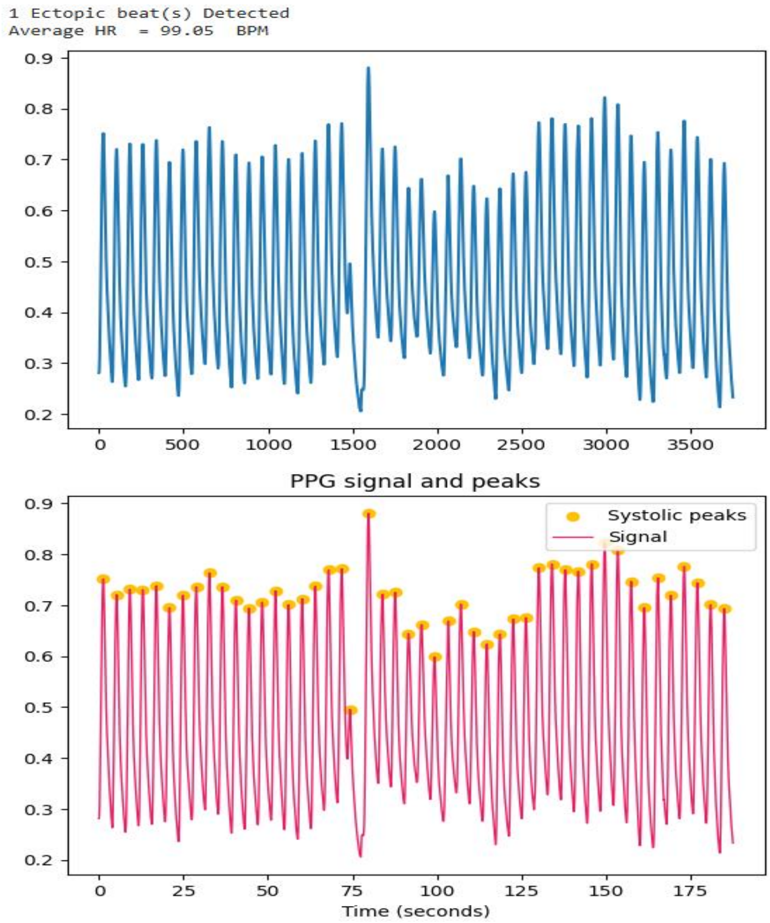

Fig.6.3. b. The resultant Output of data in Fig. 6.3. a.

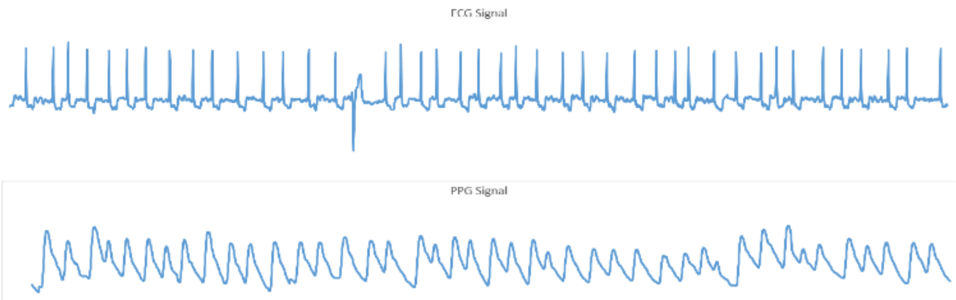

Fig.6.4. a. ECG and PPG Signal in Atrial Fibrillation subject-1.

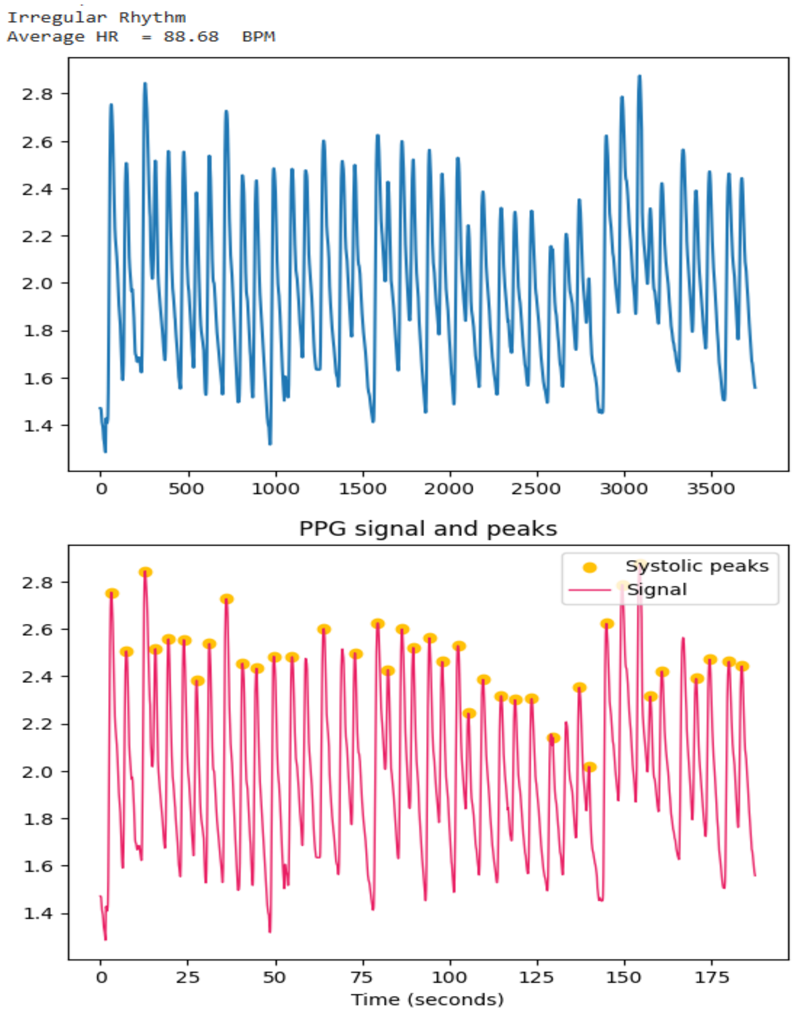

Fig. 6.4.b. Output of Atrial Fibrillation Subject-1.

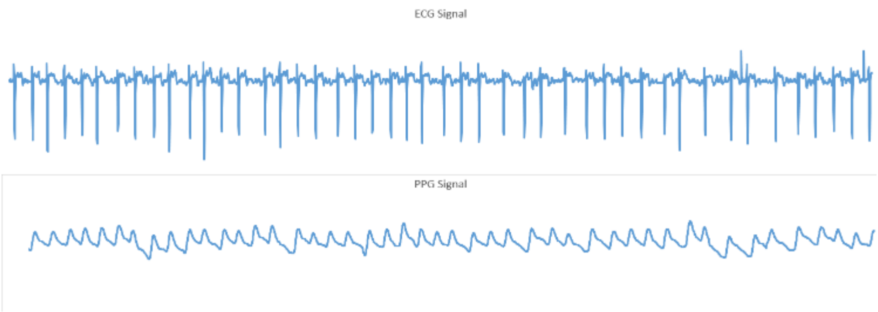

Fig.6.5. a. ECG and PPG of Atrial Fibrillation subject-2

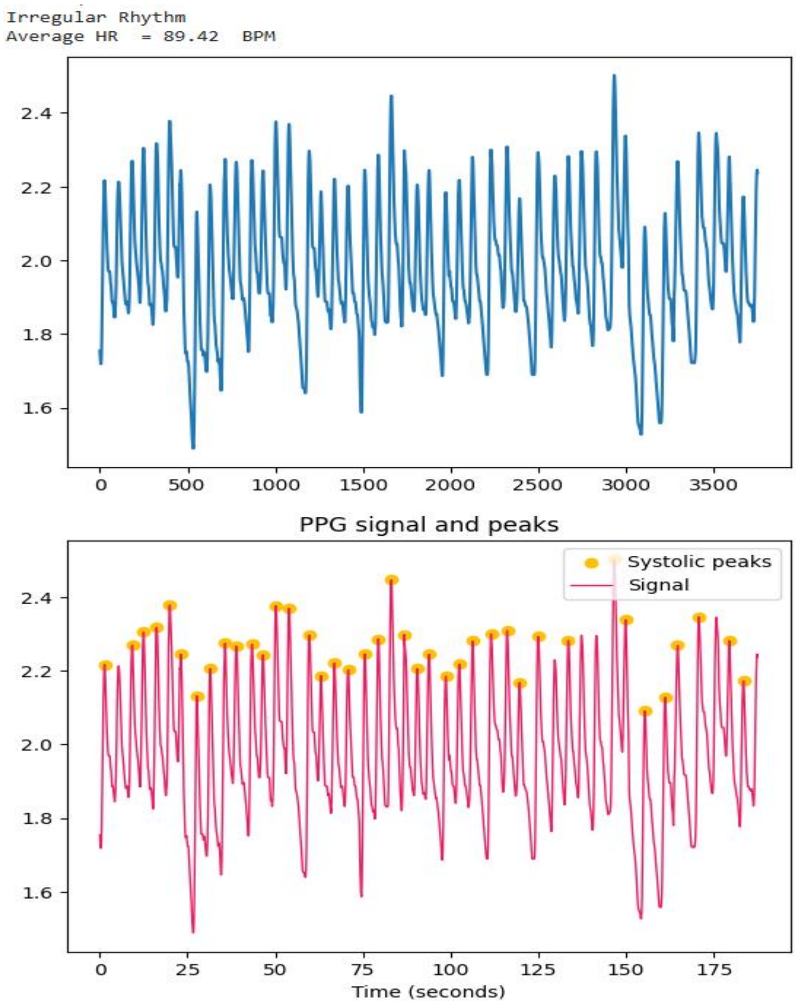

Fig.6.5. b. Output of Atrial Fibrillation subject-2.

The figure 6.3.a. is the 15 seconds data of subject with ectopic beat. The output detects and mentions as ectopic beat detected as shown in figure 6.3.b. The figures 6.4.a. and 6.5.a. shows 15 seconds data of atrial fibrillation.
The algorithm detects the rhythm and mentions Irregular rhythm in outputs figures 6.4.b. and 6.5.b. As you can see the output images has 2 graphs, the blue graph is the clean PPG signal data and the red graph is peak detected signals.

IV. CONCLUSION

The future plan is to design a very compact device similar to a pulse oximeter, with inbuilt SPO2 sensor and Bluetooth module. This Bluetooth module can communicate with Mobile phones, Laptops or even Arduino. Since NeuroKit2 is open source, we can use it to analyze and interpret the plethsymogram anytime and anywhere. This project will be useful for elderly people and even in some emergency situations.

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