

# Identification of R-peaks to Detect Ventricular Fibrillation, Ventricular Tachycardia and Atrial Fibrillation

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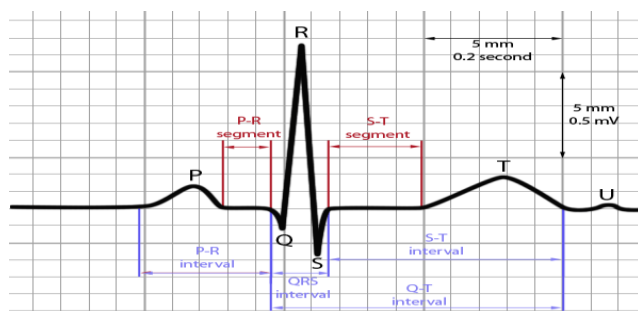
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**Abstract:** Many types of arrhythmias are identified by where they occur in the heart either in the Atria or Ventricles and what happens to the heart rhythm when they occur. Arrhythmias that begin in the atria are called atrial or supraventricular arrhythmias. Arrhythmias that begin in the ventricles are called ventricular arrhythmias. These ventricular arrhythmias begin in ventricles. The rhythm of heart can be measured using ECG signal. In this work, we are detecting R-peaks using Pan and Tompkins algorithm by which we are calculating the heart rate from ECG signal. These heart rate and abnormalities in ECG signal help us to detect VT (Ventricular Tachycardia), AF (Atrial Fibrillation) and VF (Ventricular Fibrillation). This Pan and Tompkins algorithm is implemented using MATLAB.

**Keywords:** ECG, Pan-Tompkins algorithm, R-peaks

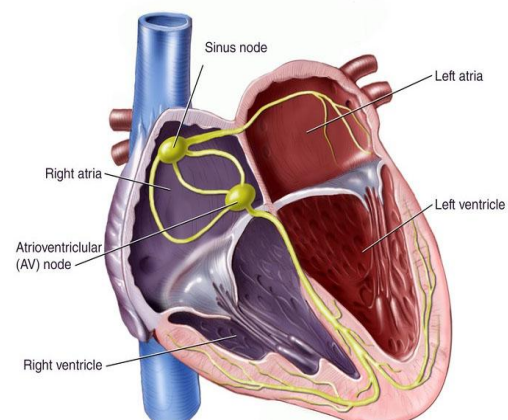
## 1. Introduction

Arrhythmia means abnormal beating of heart. In which increase in heart beat is called Tachyarrhythmia and decrease in heart beat is called Brady arrhythmia which leads to heart attack [1]. Arrhythmia is due to abnormal conducting of tissue within the heart, it could be in atria or ventricle. The graphical representation of cardiac movement which is generated by the cardiac muscle is called ECG. The ECG with PQRST peaks are shown in the fig.1.



**Figure 1:** Normal ECG signal with PQRST peaks.

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**Figure 2:** Cardiac Arrhythmia

Main concern in this topic is,

- Atrial Fibrillation (AF)
- Ventricular Tachycardia (VT)
- Ventricular Fibrillation (VF)

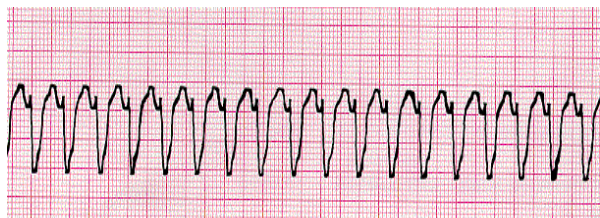
Now let's discuss about the mechanism of AF, VT and VF in detail.

### • Ventricular Tachycardia:

In Ventricular tachycardia (VT) the heart rate is fast and regular, which occurs in ventricles during the abnormality of the heart. Only for few seconds it may not cause problem, longer duration lead to VT and it can turn into VF. Initially in 7% of the people with cardiac arrest VT is found. Heart rate reaches up to 150-200bpm.

### Definition:

**Ventricular tachycardia (VT)** is a type of regular and fast heart rate that arises from improper electrical activity in the **ventricles** of the heart.



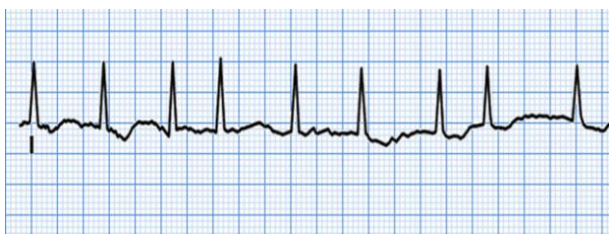
**Figure 3:** VT detected ECG sample

• **Atrial fibrillation:**

In Atrial fibrillation (AF) the main mechanism is re-entry, which takes over SA node and makes the heart beat fast. So in atrial fibrillation and flutter atria beat faster than ventricle and gets impulses after many atrial contractions. AF leads to shortness of breath and chest pain there may be a risk of heart failure and stroke. Heart rate reaches up to 100-150bpm.

**Definition:**

**Atrial fibrillation**, known as AF or **A fib**, is an irregular and often very fast heart rate.



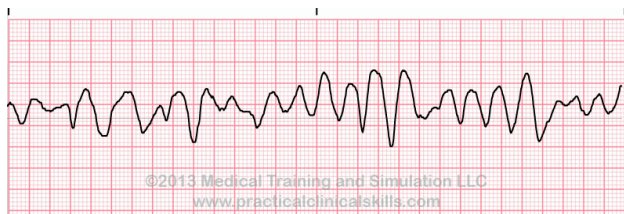
**Figure 4:** AF detected ECG signal

• **Ventricular fibrillation:**

VT, presenting with 300bpm heart rate is called VF. ECG shows irregular extremely fast, small potential fluctuation in rate. It is fatal condition. As fast beating heart cannot pump blood leads to sudden death. In VF heart rate reaches up to 200-300bpm and above.

**Definition:**

An abnormal and irregular heart rhythm in which there are uncoordinated contractions of the lower chambers of the heart.



**Figure 5:** VF detected ECG signal

## 2. Methodology

In this chapter, let's discuss about how the ECG signal processing can be done and how it can be extracted to give input, methodology and algorithm which has been used for the implementation.

**Extraction of ECG signal:**

The ECG signal can be taken by physionet.org website. With the help of MIT-BIH arrhythmia database we can get normal

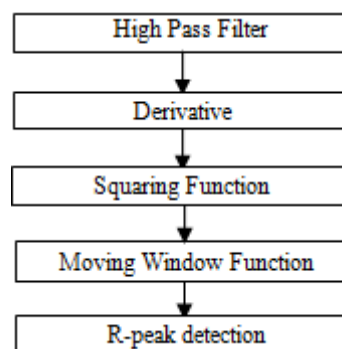
as well as abnormal patient database. There we have physio toolkit software to extract and read the .dat file called rddata.m file. Run this code using MATLAB and extract the ECG .dat signal and give this as an input to your MATLAB code to detect required cardiac arrhythmia.

Database which we have taken for VT and VF are from physionet.org under Creighton University Ventricular tachyarrhythmia Database. This database includes 35, 8 minutes ECG recordings of patient who has experienced VT and VF. In that cu01, cu03 and cu12 are VFIB records and remaining are VT records. These signals are digitized at 250Hz with 1V/mV signal. All signals are passed through LPF with 70Hz cut-off frequency and each record contains 127,232 samples. 418.dat is VT signal which has duration of half an hour, and 35.dat, 36.dat and 37.dat are AF recording which have been considered from MIT-BIH arrhythmia database library.

**Block diagram implementation using MATLAB:**

One of the simplest recognition of VT, AF and VF is based on the measurement of cardiac rate which can be detected with the help of algorithm. Here we have used Pan and Tompkins algorithm to detect QRS complexes in ECG signal.

Block diagram consist of high pass filter, derivative filter, squaring function, moving window function and R-peak detection block which has been shown below,



**Figure 6:** Block diagram representation of Pan and Tompkins algorithm

Each block of Pan and Tompkins algorithm is explained below,

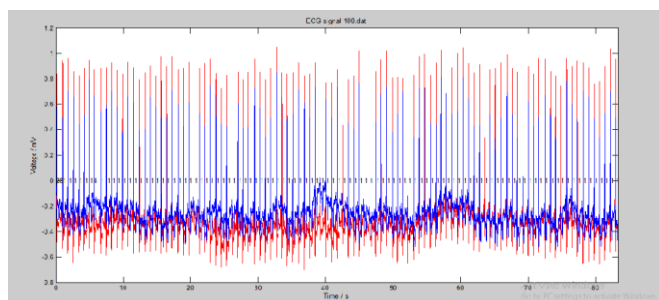
- In the first step of the algorithm, the ECG signal goes through a band-pass filter to attenuate the P and T wave of ECG signal, so that to remove low frequency components of the ECG with pass band of 5-12Hz. Which is the combination of both low pass and high pass filter, LPF with cut-off frequency of 11Hz and HPF with cut-off frequency of 5Hz is used.
- After filtering P and T wave of ECG, the signal is differentiated to amplify the QRS edges.
- The differentiated signal has positive and negative points; it is then squared to get a signal which has only positive peaks.
- The steeper parts which are detected in the differentiated filter are amplified and squaring function will exhibit multiple peaks within duration of single QRS complex.

- To make the signal smoother Pan and Tompkins algorithm uses moving window function.
- Finally, R-peaks are detected and heart rate is calculated.

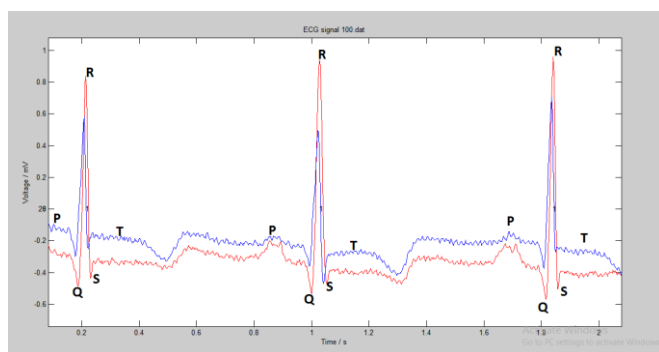
### 3. Results

#### 1) Normal ECG signal

The output shown below is the input ECG signal (Normal) which is in .dat, .hea and .atr format. This signal is extracted from Physionet.org website where we can get number of ECG signals. ECG database 100.dat file is shown below,



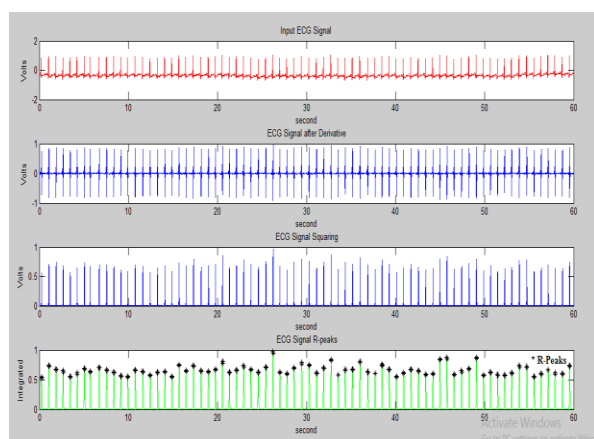
**Figure 7: Input ECG 100.dat**



**Figure 8: Zoomed in view of 100.dat**

#### Output of normal ECG signal

The output consist of 4 graphs, first the input signal which has been passed through BPF to remove P and T waves of input ECG. After that the signal differentiated, and then it is squared to remove negative peaks of the differentiated signal so that we can get only QRS complexes. By determining R-peaks we can easily calculate the heart rate. Output graph is shown below, which is of 60s window and detected R-peaks are 74.

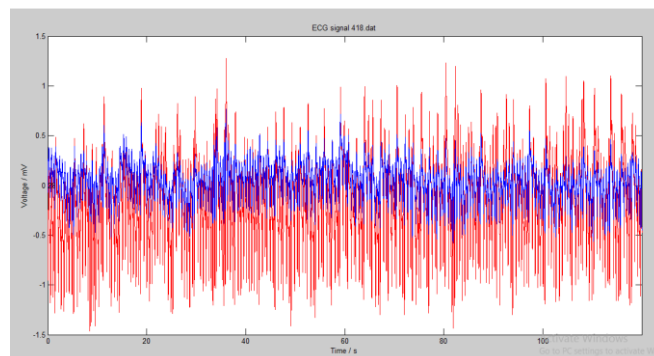


**Figure 9: Output of 100.dat ECG**

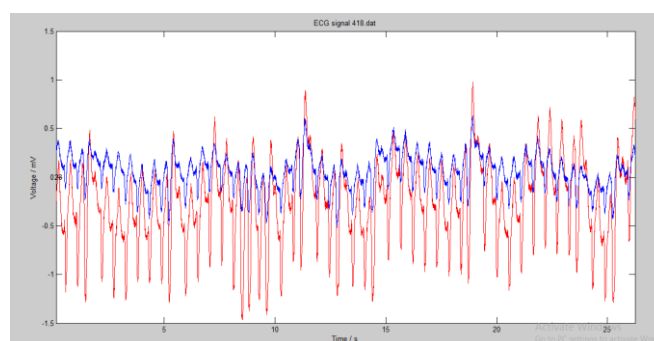
#### 2) Ventricular Tachycardia

As we taken for input ECG the same procedure repeats for VT signal. Here if we compare input ECG with VT signal the number of R-peaks are more compared with input.

Here, we have considered 418.dat file which represents Ventricular Tachycardia which consists of Time/s along x-axis and Voltage/mV along y-axis.



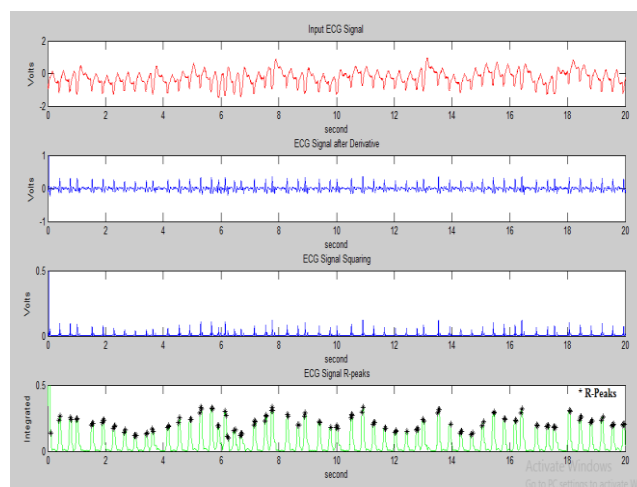
**Figure 10: VT input 418.dat ECG**



**Figure 11: Zoom in of VT input 418.dat**

#### Output of VT detected ECG:

The output waveform of 20s window which has four plots, in which first plot represents input VT signal, second represents the signal after derivative function has been applied, which has both positive and negative edges, to remove negative edges square the derivate signal to get only positive peaks. Finally in the fourth plot R-peaks are detected.



**Figure 12: Output of 418.dat VT signal**

### 3) Atrial Fibrillation

AF and VT are same but here R-peaks are very clear compared to VT and VF. The output of the AF when implemented through algorithm is shown below, We have considered 20s window.

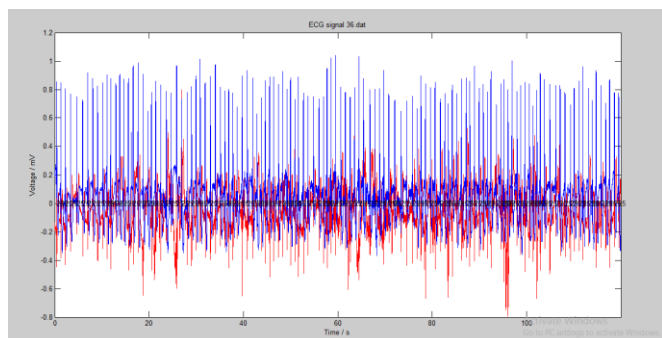


Figure 13: Input AF signal 36.dat

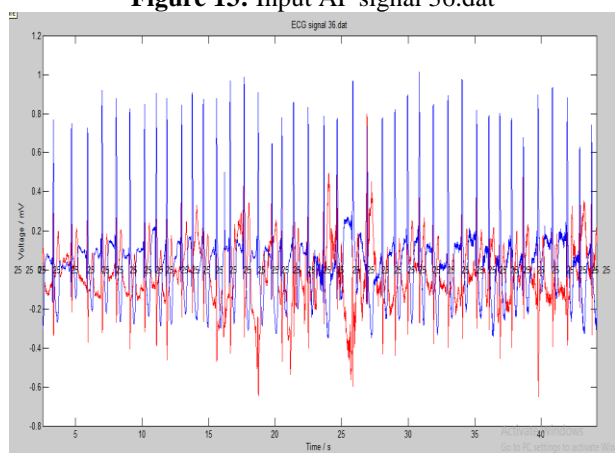


Figure 14: Zoom in of AF input 36.dat

#### Output of AF detected ECG:

The output waveform of 20s window which has four plots, in which first plot represents input AF signal, second represents the signal after derivative function has been applied, which has both positive and negative edges, to remove negative edges square the derivate signal to get only positive peaks. Finally in the fourth plot R-peaks are detected.

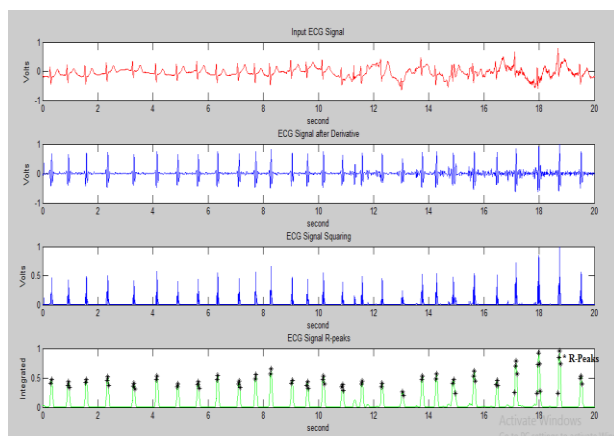


Figure 15: Output of 36.dat AF signal

### 4) Ventricular Fibrillation

It is different from VT and AF. The heart rate reaches above 200, the R-peaks are more. But here we cannot recognise R-peaks properly. The output is shown below,

Here 10s window has been considered and detected R-peak count is 50 and heart rate reaches up to 300.

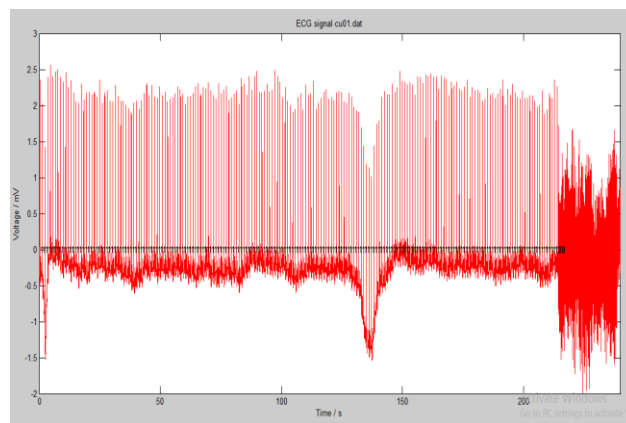


Figure 16: Input of cu01.dat

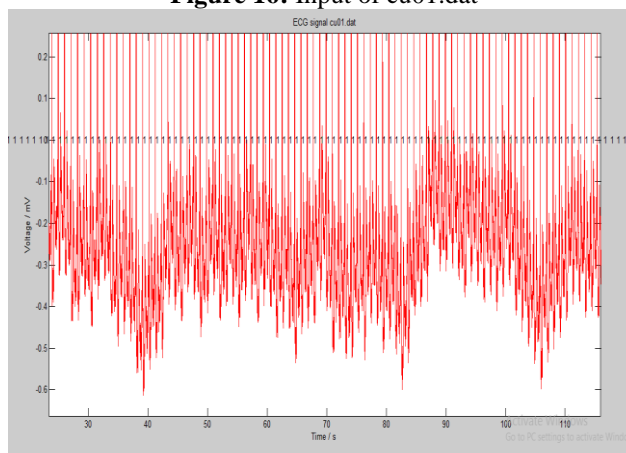


Figure 17: Zoomed in view of cu01.dat

#### Output of VF detected ECG:

The output waveform of 20s window which has four plots, in which first plot represents input VF signal, second represents the signal after derivative function has been applied, which has both positive and negative edges, to remove negative edges square the derivate signal to get only positive peaks. Finally in the fourth plot R-peaks are detected.

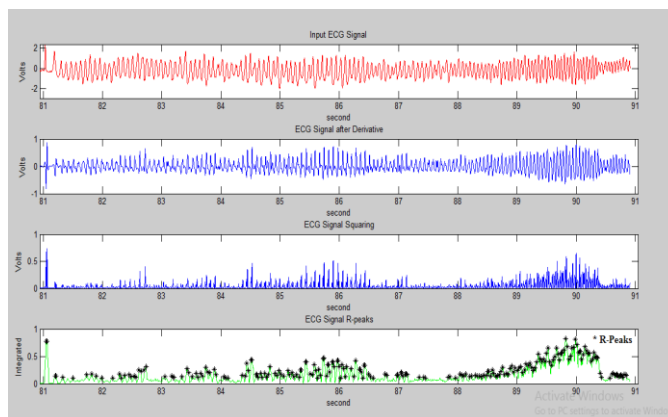


Figure 18: Output of cu01.dat VF signal

### 4. Calculation Results

To calculate number of R-peaks we have to measure overall length of the signal and in that how many R-peaks are there we have calculated by using,

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- length (peaks)

Mean RR-interval is calculated using,

- AverageDistance\_Peaks

(Calculates average distance between R-peaks)

Using this RR-interval we can calculate frequency as,

- $F=60/RR$

Here we are calculating frequency per minute of the signal so we have considered 60 in the formula.

To calculate total error detection rate, consider the formula:

$$\text{Total error detection rate} = \left( \frac{FP+FN}{\text{Total no. of R-Peaks}} \right) 100$$

Where, FP=False Peak Detection

FN=Failure to Detection

**Table 1:** R-peaks of ECG signals

ECG signals taken from physionet.org	Number of R-peaks
Normal ECG 100.dat	74
VT detected ECG 36.dat	167
AF detected ECG 418.dat	169
VF detected ECG cu01.dat	278

**Table 2:** Mean RR-Interval

ECG Signals taken from physionet.org	Average Distance between peaks in seconds
Normal ECG 100.dat	128.4828
VT detected ECG 36.dat	107.0144
AF detected ECG 418.dat	106.4286
VF detected ECG cu01.dat	64.7225

**Table 3:** Frequency

ECG Signals taken from physionet.org	Frequency in mHz
Normal ECG 100.dat	468.75
VT detected ECG 36.dat	186.89
AF detected ECG 418.dat	187.91
VF detected ECG cu01.dat	309.21

## 5. Conclusion

In this work, the algorithm has been implemented to identify R-peaks to detect VT, AF and VF. The algorithm is called Pan and Tompkins algorithm. This algorithm helps to detect R-peaks in the ECG signal so that we can measure heart rate, total number of R-peaks in the signal, Mean RR-interval and Frequency of the signal. Then based on the heart rate we can detect whether the signal is normal or abnormal. This can be implemented in many of the applications signal processing using cell phone platform, GUI based detection using VHDL etc.

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