Lahore University of Management Sciences
Syed Babar Ali School of Science and Engineering, Department of Electrical Engineering
EE100 – Engineering Laboratory

Fall 2020

Project 2 – Handout

Arrhythmia Detection through ECG

1. OBJECTIVE: Develop a system to identify the irregularities/arrhythmia in Electrocardiography (ECG) wave with the help of patient data.

2. BACKGROUND DETAIL: It is common knowledge that heart is one of the most important parts of our circulatory system. It is responsible for pumping oxygen-rich blood throughout a person's vessel system. Heart approximately pumps 2,000 gallons of blood every day to the vessel system. Moreover, if you were to stretch out your vessel system, it would extend to over 60,000 miles. The heart has multiple valves which close and open within milliseconds and makes a beating sound. ECG is electrical activity in one cardiac cycle which in turn makes a PQRST wave (complex) as shown in Fig. 1. Irregular, slow, fast electrical rhythms are known as Cardiac Arrhythmias (CA). Cardiac arrhythmias are caused by disorders in electrical conduction disorders. When the heart is beating too fast it is known as tachycardia and when the heart is beating irregularly or too slow then it is known as bradycardia. Over the years, ECG has become an integral tool for detecting cardiovascular diseases/Arrhythmia. However, as a result of technological advancement, one can detect irregularities in an ECG with the help of automated systems. For that, a Real-Time ECG detection system needs to be developed to continuously monitor ECG and concurrently detect any irregularities in the wave. As shown in Fig. 1, a positive or negative deflection from baseline is made up of P, Q, R, S, T wave and each wave represents a specific electrical event. These waves have their specific location in the curve which can also be seen. When these waves are dislocated or distorted from their original location, it means that the heart is experiencing an arrhythmia which if not treated on time can be lead to mortality.

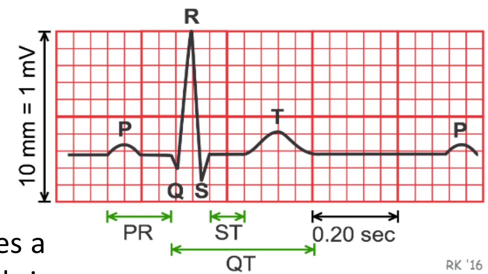


Fig. 1 PQRST

In this project, first, you will be working to plot ECG (PQRST) wave with the help of provided patient data to detect two types of cardiac arrhythmias, i.e., Premature Ventricular Contraction (PVC), and Ventricular Tachycardia (VT). Description of these arrhythmias are given below:

Premature Ventricular Contraction (PVC): PVCs are extra, abnormal heartbeats that heart rhythm, sometimes causing a skipped beat or palpitations. PVC's can be identified from a continuous ECG waveform having 2 or more of these traits: short RR interval (<0.6sec), long ST interval (>0.28 sec), or a High T-wave amplitude (>100). An episode of PVC can be seen in the ECG sample of Fig. 2.

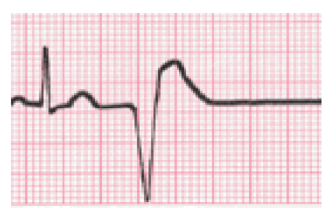


Fig. 2 PVC

Ventricular Tachycardia (VT): VT is one of the most common causes of cardiac deaths. PVC not treated on time can turn into VT. Hence, VT is 3 or more consecutive PVC's in a row. It can also be detected with the same traits as VT. An episode of VT can be seen in Fig. 3.

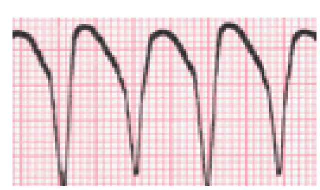


Fig. 3 VT

3. DATA DESCRIPTION: The data provided is 20-sec ambulatory ECG recording of a patient's heart. The recordings were digitized at a sampling rate of 360Hz with 11-bit analog to digital converter (ADC). Two or more cardiologists independently annotated each record. Sampling frequency (F_S) is also embedded in the .mat file. The provided data have DC offset but high-frequency noise was significantly suppressed by the analog front end.

4. STATE DIAGRAM: The state logic algorithm is implemented as shown in Fig. 4. The algorithm works on thresholds and slope changes in search windows, to find the PQRST complex features.

The system will start in state 0 and will find the R-wave, which is local maxima in one cardiac cycle, as depicted in Fig. 4. The R-wave amplitude and index can be stored and the system can go into state 1. In state 1, if the QRS complex is positive then we can look for S wave. S-wave is the negative slope change in the window of 0.4 sec after R-wave occurrence. After successful S-wave detection, the system will enter state 2 which is checking the presence of T-wave and its detection. T-wave is the maximum positive peak between current and previous R-wave. The system is put on sleep (state 3) after T-wave until the next QRS complex appears. We can go back to state 0 only after time of 0.5sec has been passed after the occurrence of 1st R-peak.

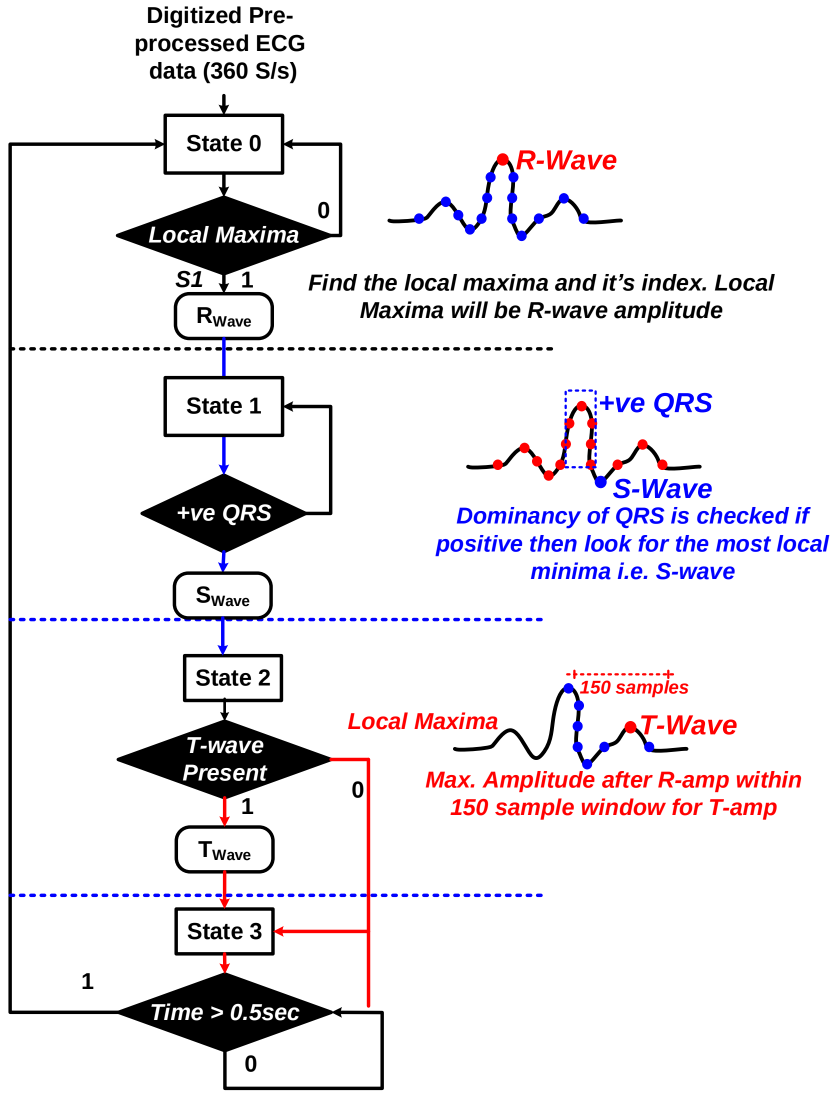


Fig. 4 State Flow Diagram

5. PROJECT TASKS: To help you achieve the overall objective highlighted above, we have split the project activities into smaller tasks; multiple tasks collected together form checkpoints which we will use to track your progress.

Task 1: Load the data provided in 1) ECG_case_1.mat and 2) ECG_case_2.mat into MATLAB and explore it:

- Plot both .mat file data patterns in the *MATLAB* having time in the x-axis with unit marked as seconds. Mark the amplitude of the ECG wave as ADC Code. [Fig. 5 shows the ECG plot of ECG_case_1.mat]
- Identify the 1) cardiac arrhythmia type, 2) no. of time-specific arrhythmia occurred, and 3) their location in seconds, in both the .mat files through the naked eye.
- Provide the conditions based on which you have declared specific PQRST complex as specific arrhythmia type. (Zoom in to see the duration and correlate with the information provided in the background section)

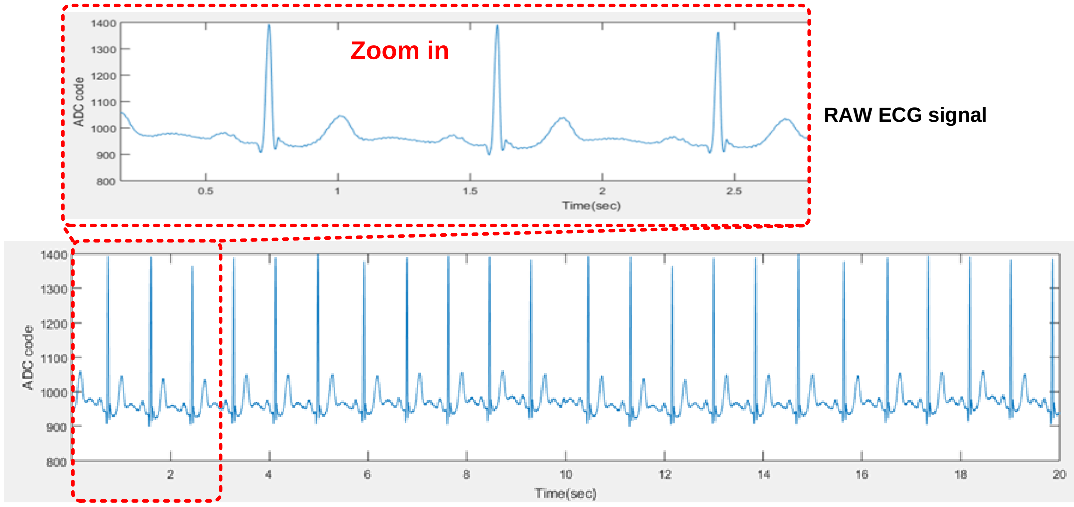


Fig. 5 ECG plot of ECG_case_1.mat

Task 2: Cardiac arrhythmia is an alarming condition for developing a cardiovascular disease that can be monitored non-invasively using heart rate variability (HRV). HRV parameters measure the difference in time periods between each two consecutive cardiac cycles. It is a useful tool to examine the health of the cardiovascular system. Conventionally, it is measured by analyzing the R-R interval variation from electrocardiography (ECG) signal. Determine the average heart rate (HR) and HRV for ECG_case_1.mat data and provide following.

1. Remove the offset / DC value and high-frequency noise from the ECG data (use ECG_case_1.mat). Hint: The band of interest is 0.5-45Hz, therefore use filter to get rid of any other signal (noise) below 0.5Hz and after 45Hz. [Fig. 6 shows the filtered response]
2. Find the local maxima to find the R-wave peaks and corresponding indices. Find the average beat per min (bpm) the same way you have found in Lab 6. Moreover, plot HRV in bpm with time in seconds. Observe any significant HRV across the individual cardiac cycle.

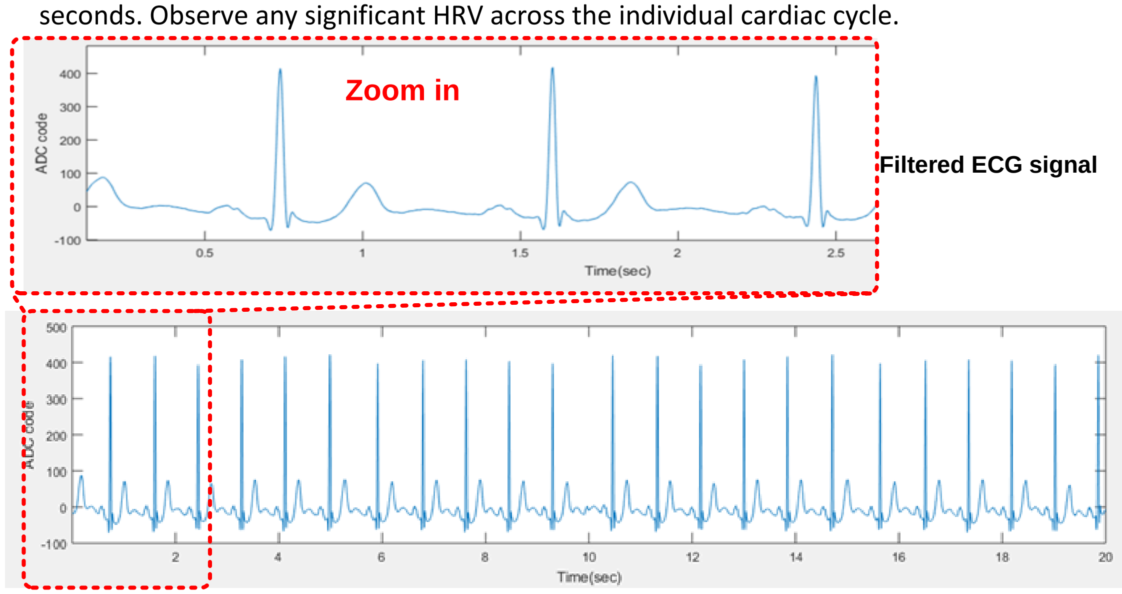


Fig. 6. Filtered ECG plot of ECG_case_1.mat

Task 3: For a wearable ECG device it's not possible to process all ECG data for arrhythmia detection. Therefore, we need to identify specific features which are helpful for the detection of mentioned two arrhythmias. The following features that can assist you in detecting the mentioned cardiac arrhythmias.

3. Amplitude and index of R-wave

4. Amplitude and index of S-wave
5. Amplitude and index of T-wave

Write MATLAB code to identify all of the above features and mark them on the processed ECG plot from Task 2 (use ECG_case_1.mat), as shown in Fig. 7.

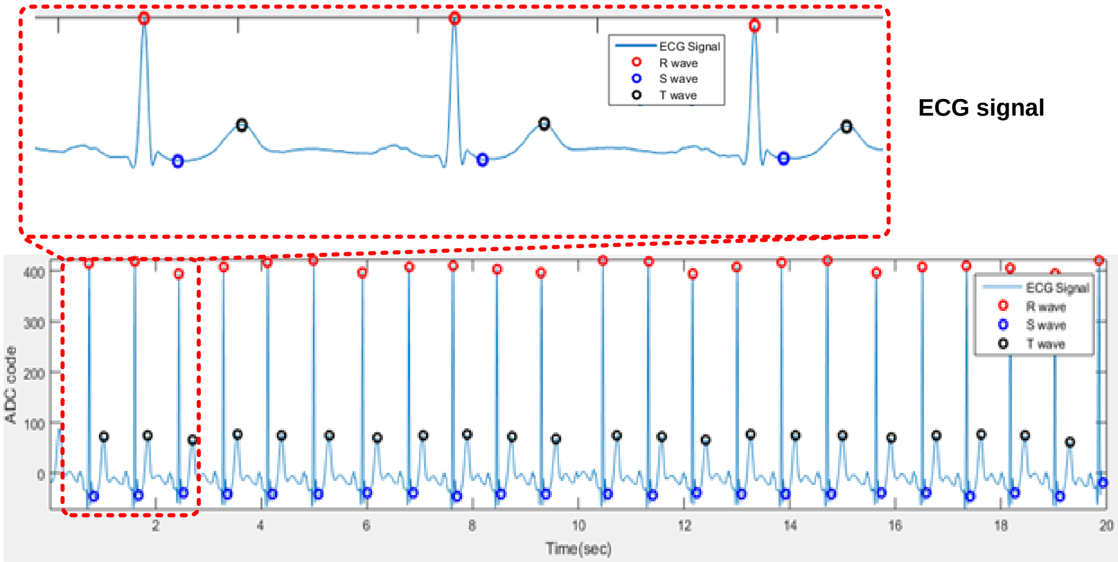


Fig. 7. ECG plot of ECG_case_1.mat with features marked

Task 4: Apply the MATLAB code developed in task 3 on the ECG_case_2.mat data. It should successfully mark all the features (amplitude and indices of R-wave, S-wave and T-wave). Modify the code and your logic in case of any discrepancy [you might need to go through the state flow diagram again]. Provide the code and plot accurately marking all the features (as shown in Fig. 8).

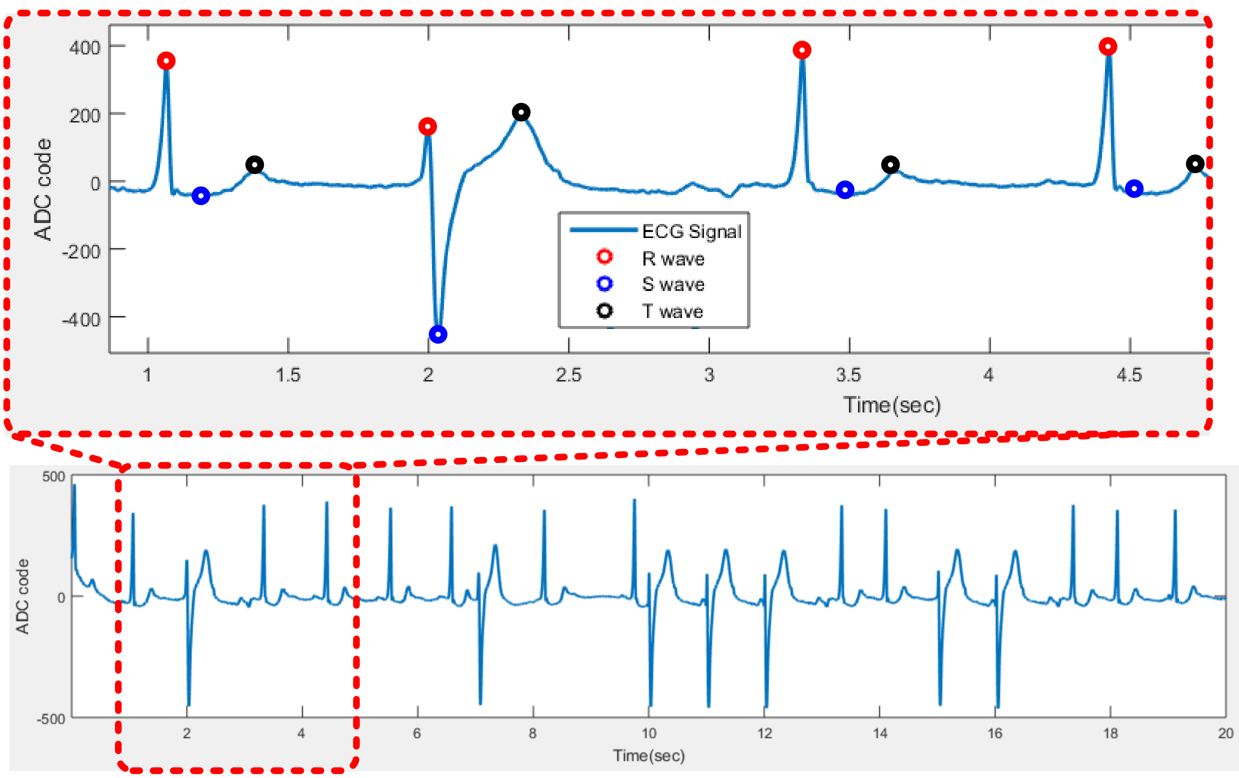
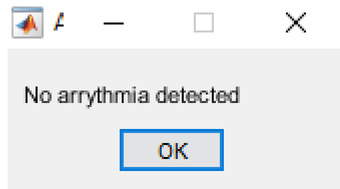


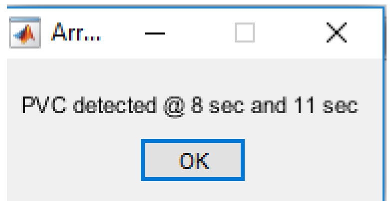
Fig. 8 ECG plot of ECG_case_2.mat with features marked

Task 5: Using the features determined in Task 4, write a MATLAB code which can detect PVC and VT from the ECG data. Apply the developed code to both data patterns (ECG_case_1.mat and ECG_case_2.mat). Moreover, display the following messages:

a) If no arrhythmia is detected in specific data pattern then the code should display following for that:



b) If any of arrhythmia is detected, display its name and occurrence at a specific time. For example, if your code detects two PVC at 8 sec and 11 sec then the following message should be displayed.



CHECK POINTS AND TIME LINES

S. No	Tasks	Deadline	Instructions
1	Project selection and Team formation	**Monday, Nov 30, 5:00 pm**	Send an email to Hamza Ather (20100003@lums.edu.pk) indicating your choice of project and a list of team members. **Max. No. of Team Members**: 3 **Min. No. of Team Members**: 2
2	**Check Point 1:** Tasks 1,2,3 • Plots of both ECG data patterns • Complete understanding of data • HR and plot of HRV • Plots of features on the ECG data (ECG_case_1.mat)	**Friday, Dec 4, 6:00 pm**	You will be assigned a dedicated TA who will track your progress. Show your code and results to the TA in the lab/office hours.
3	**Check Point 2:** Tasks 4,5 • A plot of features on the ECG data (ECG_case_2.mat) • Automatic Arrhythmia detection and message display for both data patterns.	**Friday, Dec 11, 6:00 pm**	Show your code and results to your TA in the lab/office hours.
4	Code Submission	**Saturday, Dec 12, 8:00 pm**	Submit your MATLAB code.
5	Demo Video (Optional)	**Saturday, Dec 12, 8:00 pm**	Record a 5-10 minute presentation (e.g., using Zoom) explaining your design choices, your implementation, as well as your results. Selected videos may be featured on the department's website/social media page.