UNIVERSITY
OF MIAMI

A novel recurrence quantification analysis for cardiac arrhythmia detection in multi-channel ECG signals

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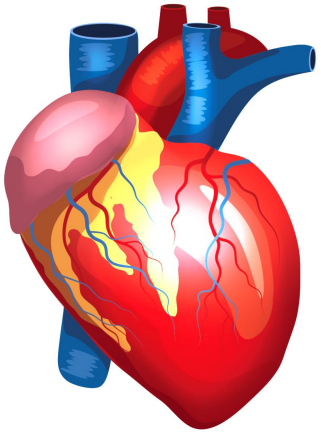
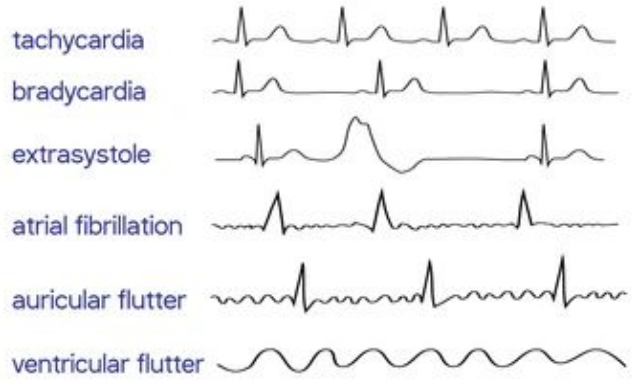
Introduction

Cardiac Arrhythmias

- An abnormality of cardiac rhythm is called cardiac arrhythmia.
- Arrhythmias may cause sudden death, stroke, heart failure, shortness of breath etc, each year around 500,000 deaths in united states occur due to arrhythmia.
- However, there can 15-20% decrease in number of deaths if there is a correct and early diagnosis.
- These Multichannel ECG signals are complex in nature and difficult to interpret and detect the anomalies.
- We propose an methodology to detect such kind of anomalies in ECG signals and revert the accidents before they actually occur.



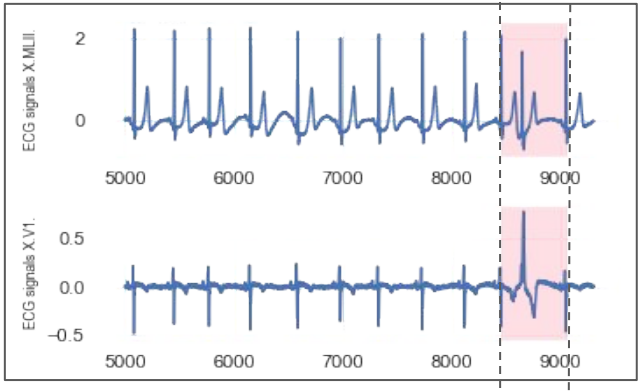


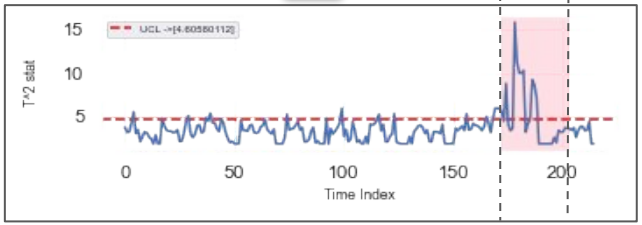
Different Types of Arrhythmias.

Research Framework

1. Multichannel ECG Signals

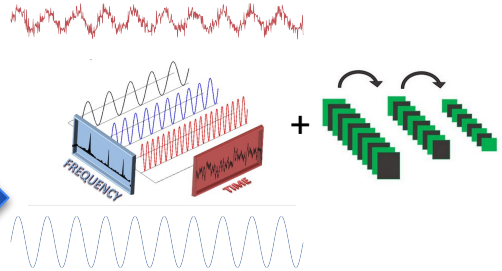
Cardiac Arrhythmia



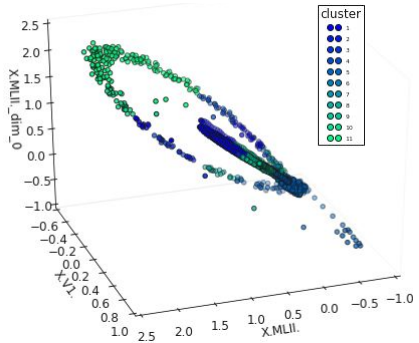


2. Signal Preprocessing

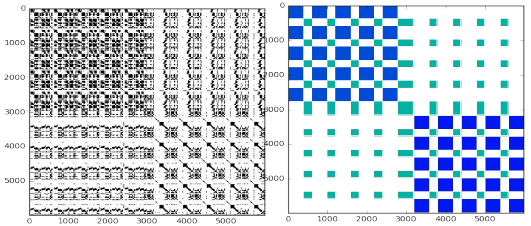
FFT & Embedding



3.State Space Representation & Segmentation



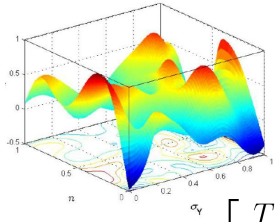
Transition-recurrence plot ***ε-recurrence plot***



$$R = H(\epsilon - ||s_i - s_j||)$$

4.Recurrence Representation

$$R(\pi) = H(||\pi(s_i) - \pi(s_j)||) * \pi(s_i)$$



$$TRQA = f(R, R(\pi)) = \begin{bmatrix} TRR \\ TDET \\ \dots \\ TLAM \end{bmatrix}$$

5.Transitional Recurrence Quantification

6. Multivariate Anomaly Detection

Proposed Recurrence Quantification Analysis

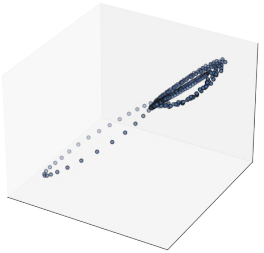
State Space Representation
(continuous)

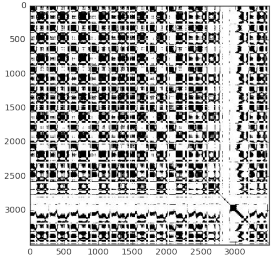
State Recurrence
(ϵ-Recurrence Plot)

Recurrence Analysis Quantification
(conventional RQA)

Multichannel Time Series

x
y
z

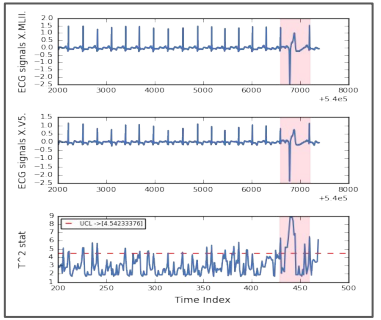




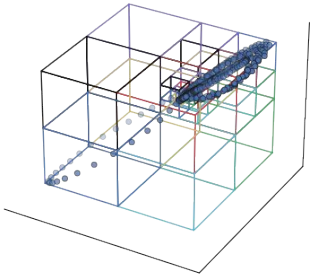
$$R = H(\epsilon - ||s_i - s_j||)$$

$$RQA = f(R) = \begin{bmatrix} RR \\ DET \\ \dots \\ LAM \end{bmatrix}$$

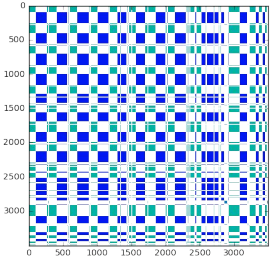
Multivariate Anomaly Detection
(Multivariate Control Chart)



State Space Segmentation
(discrete)



Transition Recurrence
(Heterogeneous Recurrence Plot)



$$R(\pi) = H(||\pi(s_i) - \pi(s_j)||) * \pi(s_i)$$

(New RQAs)

$$TRR = \sum_{ij} TR_{ij} / n^2$$

$$TRR(\pi) = \sum_{ij} TR_{ij}(\pi) / \sum_{ij} TR_{ij}$$

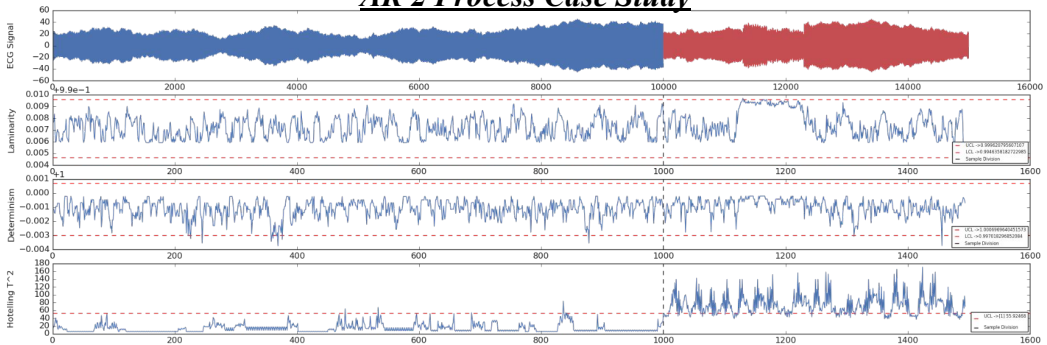
$$TDET(\pi) = \sum_{q} qL_n^{\pi}(q) / n^2 TRR(\pi)$$

$$TLAM(\pi) = \sum_{l} lL_n^{\pi}(l) / n^2 TRR(\pi)$$

$$TRQA = f(R, R(\pi)) = \begin{bmatrix} TRR \\ TDET \\ \dots \\ TLAM \end{bmatrix}$$

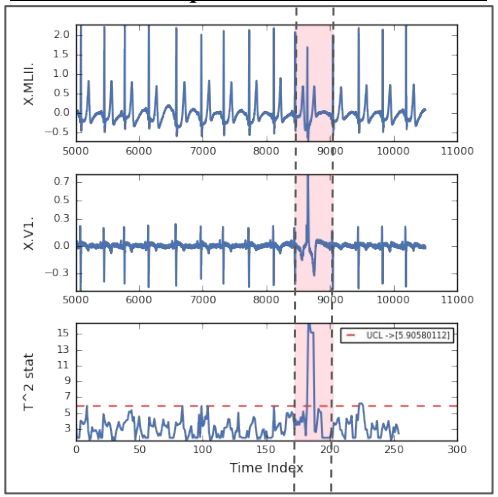
Simulation:

AR 2 Process Case Study

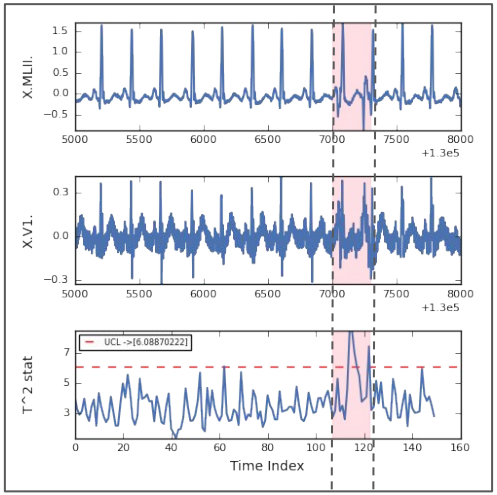


Real Case Study:

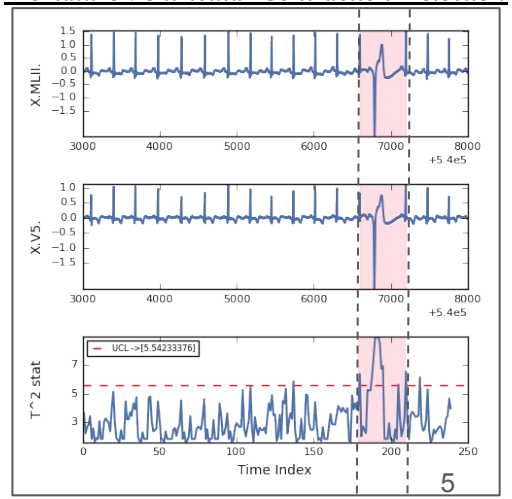
Aberrated atrial premature beat - Detection



Isolated QRS-like artifact



Premature Ventricular Contraction-Detection



MIT-BIH Arrhythmia Database

Discussion and Conclusion

- ***Accomplishments & contributions:***
  - *New framework considering the recurrence patterns of states and transitions, for anomaly detection in complex systems*
  - *Reduces ambiguities and increases information resolution*
  - *New quantifiers for transition recurrence analysis*
  - *Tested over small datasets are arrhythmias with high detection power of 96.2 %*
- ***Broader impact:***
  - *Health Care*
  - *Finance*
  - *Weather Oscillations*
  - *Business Cycles and Economic Development*
- ***Future Work:***
  - *Testing over Big Datasets and determining detection power*
  - *Characterizing different types of arrhythmia*