Pattern recognition in ECG time series

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INTRODUCTION

Introduction

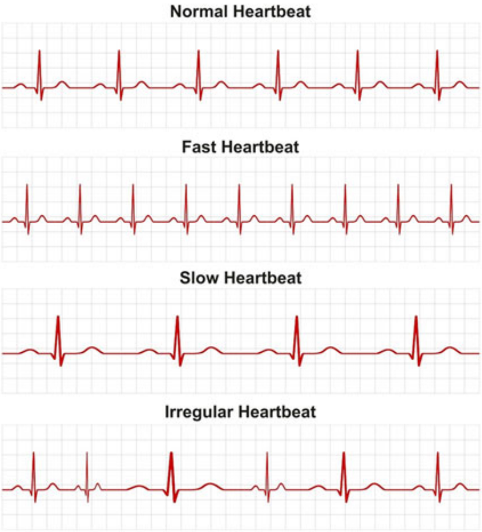

Figura 1: Heart arrhythmias.

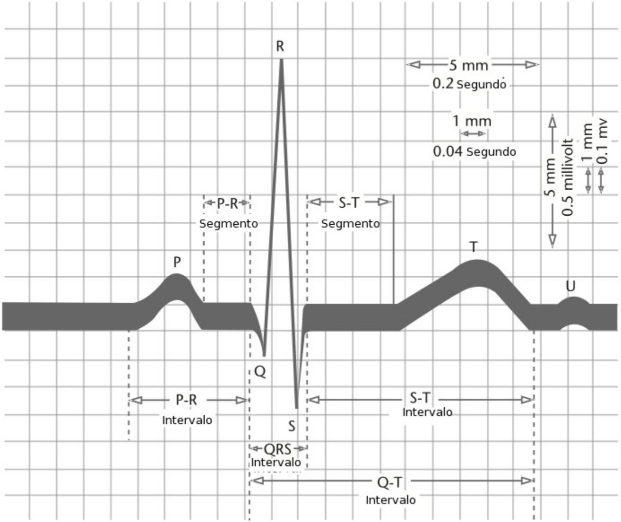

Figura 2: Features of a signal ECG (CLIFFORD et al., 2006).

Introduction

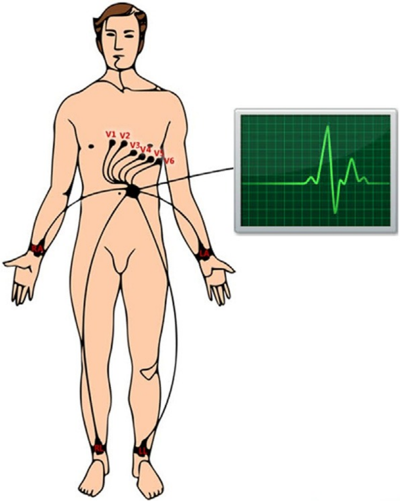

Figura 3: Typical 10 electrodes (leads) configuration (LUZ et al., 2016).

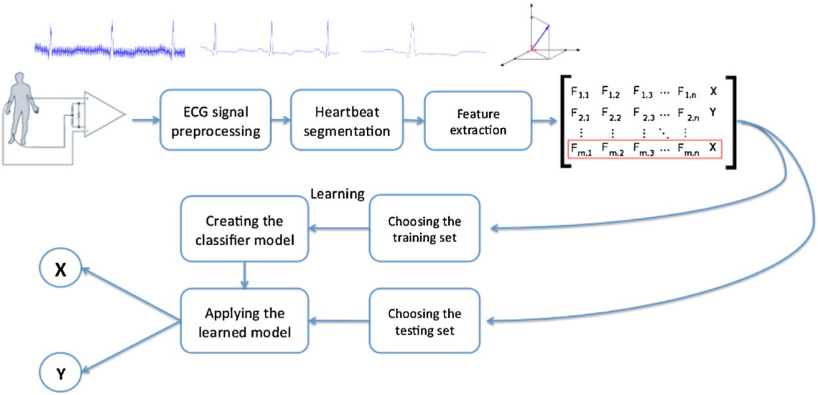

Figura 4: A diagram of the arrhythmia classification system (LUZ et al., 2016).

Introduction

- Automatic ECG classification systems has two main paradigms: *intra-patient* and *inter-patient*.
  - *Intra-patient* a subject's heartbeat is used both for building the classification system and for testing.
  - **Inter-patient* used a separate set of subjects for building the classification system, and another for testing.

*The best paradigm to simulate a real scenario.

DATABASE

- MIT-BH Arrhythmia Database (MOODY; MARK, 1990);
- Developed by MIT and Boston's Beth Israel Hospital;
- 48 annotated records (signals) obtained from 47 subjects between 1975-1979;
- Each record has 30 minutes selected from recorded 24 hours;
- Sample of 360Hz in 2 channels (V and II);
- Four records include paced beats.

Tabela 1: Mapping between MIT-BIH and AAMI* labels

MIT-BIH class	AAMI class	Number of events
Normal beat (N or .) Left bundle branch block beat (L) Right bundle branch block beat (R) Atrial escape beat (e) Nodal (junctional) escape beat (j)	Normal (N)	90125
Atrial premature beat (A) Aberrated atrial premature beat (a) Nodal (junctional) premature beat (J) Supraventricular premature beat (S)	Supraventricular ectopic beat (S)	2781
Premature ventricular contraction (V) Ventricular escape beat (E)	Ventricular ectopic beat (V)	7009
Fusion of ventricular and normal beat (F)	Fusion beat (F)	803
Paced beat (P or /) Fusion of paced and normal beat (f) Unclassified beat (U) Unknown beat (Q)	Unknown beat (Q)	15
	TOTAL	**100733**

*Association for the Advancement of Medical Instrumentation.

Dataset	Recordings
DS1 (Training)	101, 106, 108, 109, 112, 114, 115, 116, 118, 119, 122, 124, 201, 203, 205, 207, 208, 209, 215, 220, 223, and 230.
DS2 (Testing)	100, 103, 105, 111, 113, 117, 121, 123, 200, 202, 210, 212, 213, 214, 219, 221, 222, 228, 231, 232, 233, and 234.

Tabela 2: Distribution of the MIT-BIH recordings between training and testing proposed by (CHAZAL; O'DWYER; REILLY, 2004)

*AAMI recommends deleting four records with paced beats (102,104,107,217).

PROPOSED METHODOLOGY

Proposed Methodology

- MIT-BIH database and Inter-patient paradigm
- Preprocessing (Filtering)
- Segmentation (QRS Complex detection)
- Feature Extraction
- Classification

Proposed Methodology

- Preprocessing (Filtering):
  - Discret Wavelet Transform (DWT)
  - Scipy filters (Savitzky-Golay, medfilt, wiener, etc.)
- Segmentation (QRS Complex detection):
  - Normalization (0-1)
  - Extract T waves from R-peak signal annotation file
  - Arrhythmia type from annotation file
  - Length of each heartbeat: 300 samples
- Feature Extraction:
  - Discret Wavelet transform (DWT)
- Classification:
  - SVM and neural network

METHODS

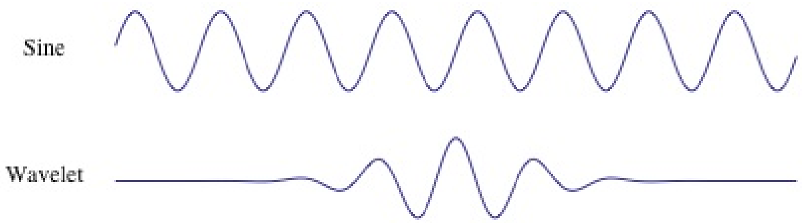

Figura 5: The difference between a sine-wave (Fourier) and a Wavelet (WT). The sine-wave is infinitely long and the Wavelet is localized in time (TASPINAR, 2018).

Wavelet $\rightarrow$ small wave.

Methods

Wavelet Transform families

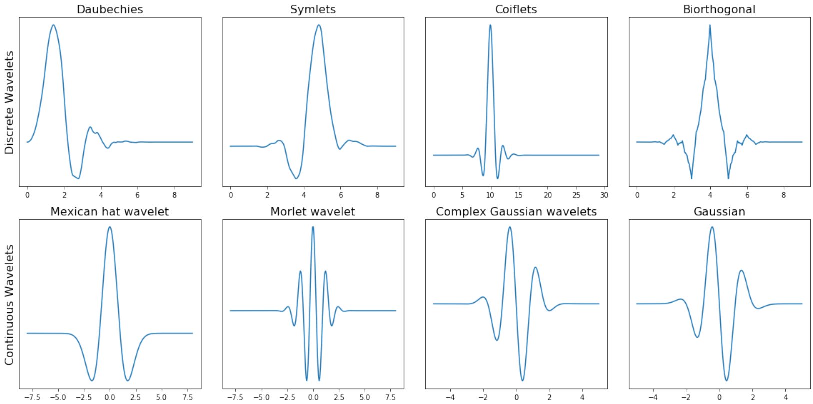

Figura 6: Some discrete wavelets families (DWT) and continuous wavelets (CWT) families. The Pywavelets library contains 14 mother Wavelets (families of Wavelets).

Each of them has different subcategories and differs from number of coefficients (vanishing moments) and level of decomposition.

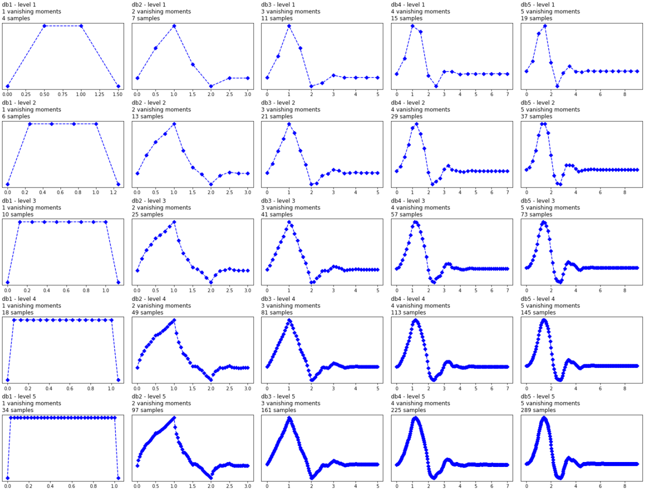

Figura 7: The Daubechies family of wavelets for several different orders of vanishing moments and several levels of decomposition.

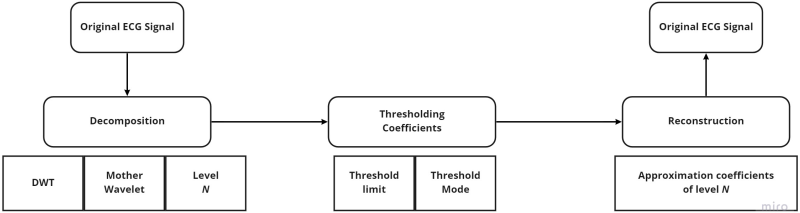

Figura 8: Noise Removal using WT Threshold method.

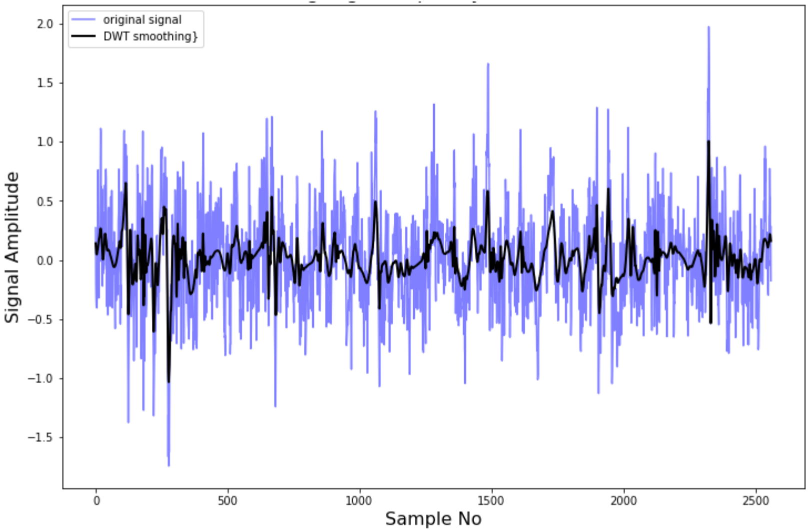

Figura 9: A high frequency signal and its DWT smoothed version.

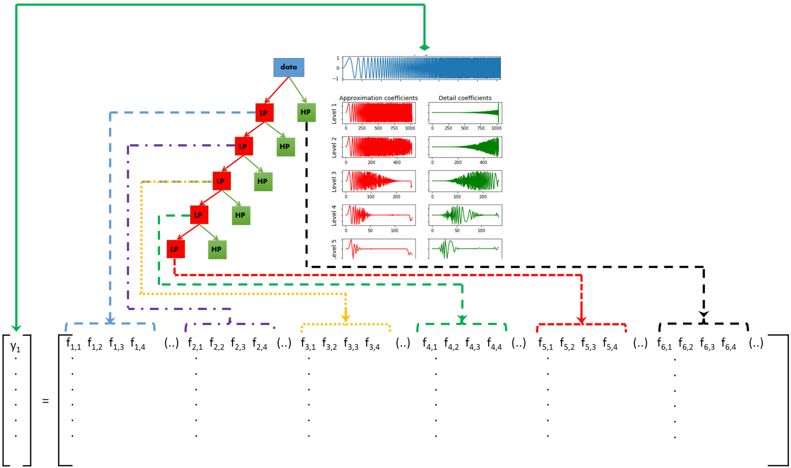

Figura 10: DWT can deconstruct signal in frequency sub-bands. And out of each sub-band it can generate features that can be used as input for a classifier.

What kind of features can be generated for each of the sub-bands?

Depend on the type of signal and the application!!!

Coefficient values	Entropy values
Statistical features	Variance
Standard deviation	Mean
Median	25th percentile value
75th percentile value	Root Mean Square value
Mean of the derivative	Zero crossing rate
Mean crossing rate	

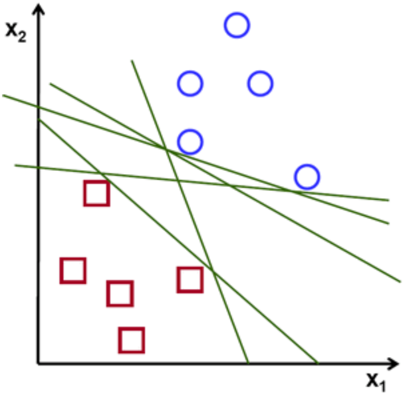

Figura 11: Hyperplanes in an N-dimensional space (N - the number of features)

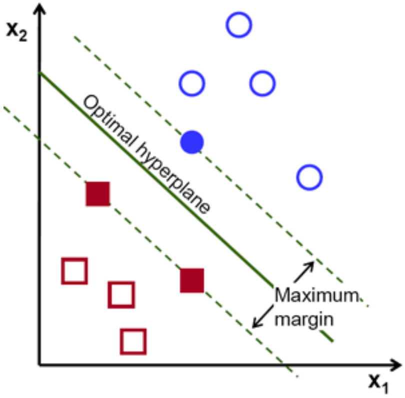

Figura 12: Hyperplanes and Support Vectors

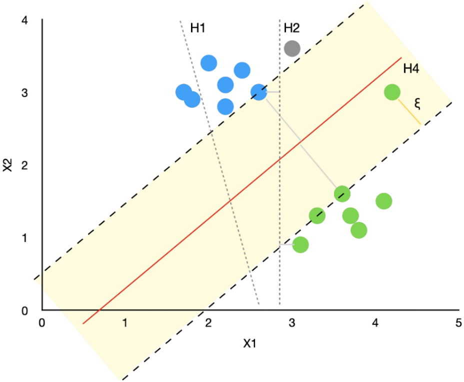

Figura 13: Soft-margin that allows for some points to be misclassified using a value ξ. It controls by regularization hypermeter **C**

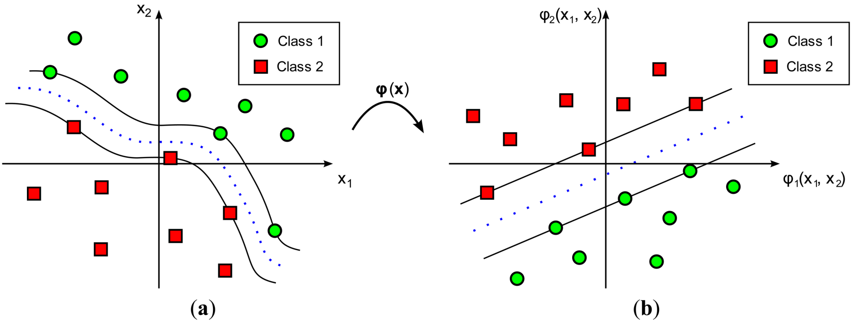

Figura 14: Non-linear SVM dimension transformation using kernel trick

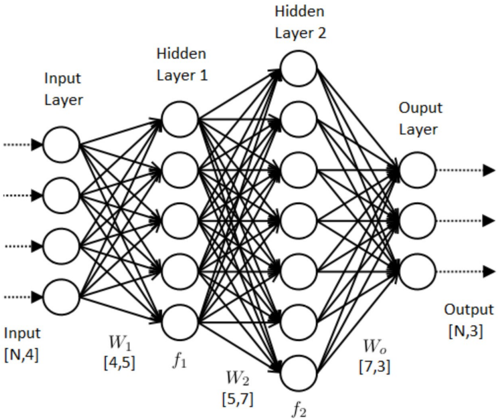

Figura 15: Artificial Neural Network

RESULTS

Modelos	Classes			
	{N,S,V,F,Q}		{N,S,V}	
	Treino	**Teste**	**Treino**	**Teste**
Gradient Boosting	**0.93**	**0.64**	**0.91**	**0.66**
SVM	0.77	0.62	0.76	0.66
Rede Neural	0.78	0.61	0.84	0.56

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"That's all Folks!"