Machine Learning in ECG

Automated detection of various cardiovascular diseases using a single-lead electrocardiogram

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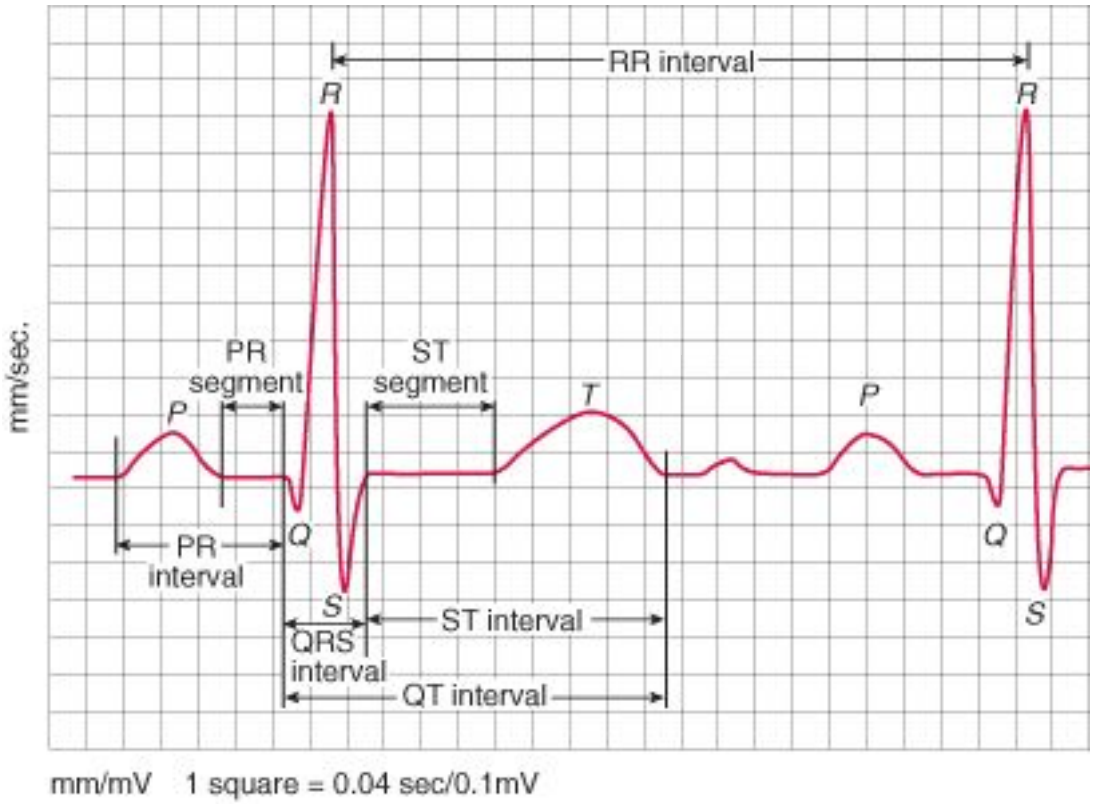
Electrocardiography (ECG)

- Method that registers electrical heart activity over a time period
- Changes in voltage during depolarization and repolarization of cardiac muscles recorded by electrodes positioned on surface of chest and limbs
- Advantages:
  - Low cost
  - Immediately available
  - Easy implementation
  - Non-invasive

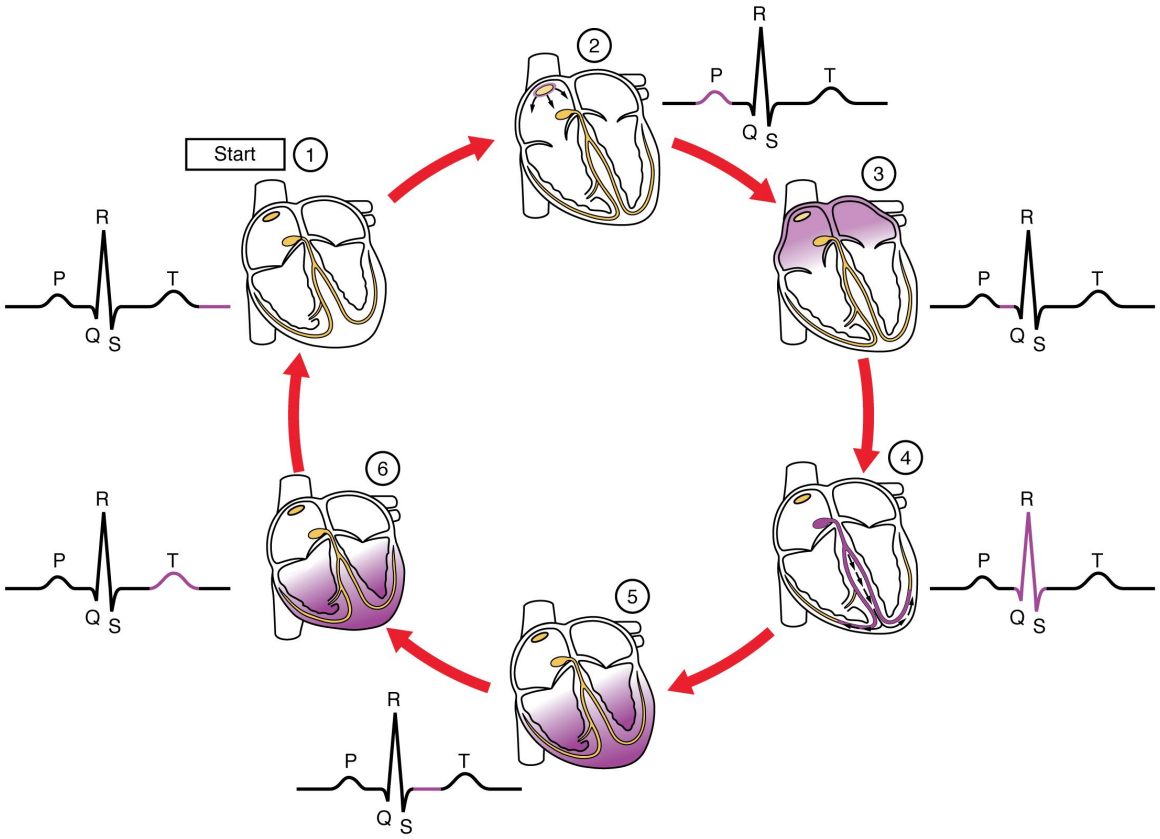
Gacek, Adam, and Witold Pedrycz, eds. *ECG signal processing, classification and interpretation: a comprehensive framework of computational intelligence*. Springer Science & Business Media, 2011.

The ECG signal



http://www.merckmanuals.com/professional/cardiovascular-disorders/cardiovascular-tests-and-procedures/electrocardiography

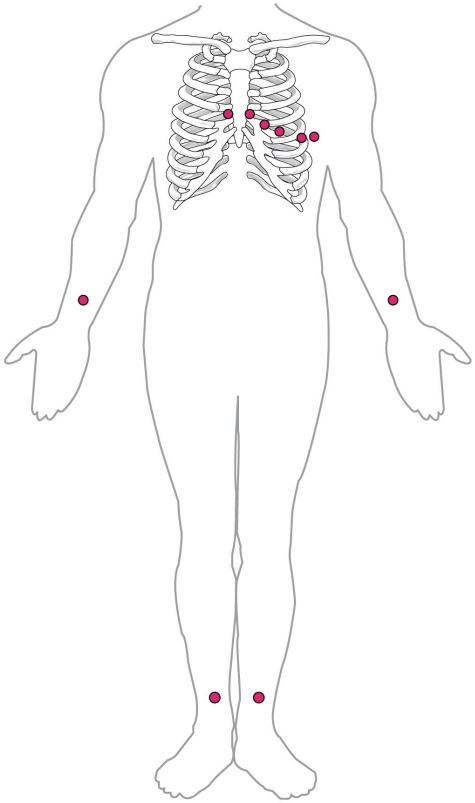
The ECG signal



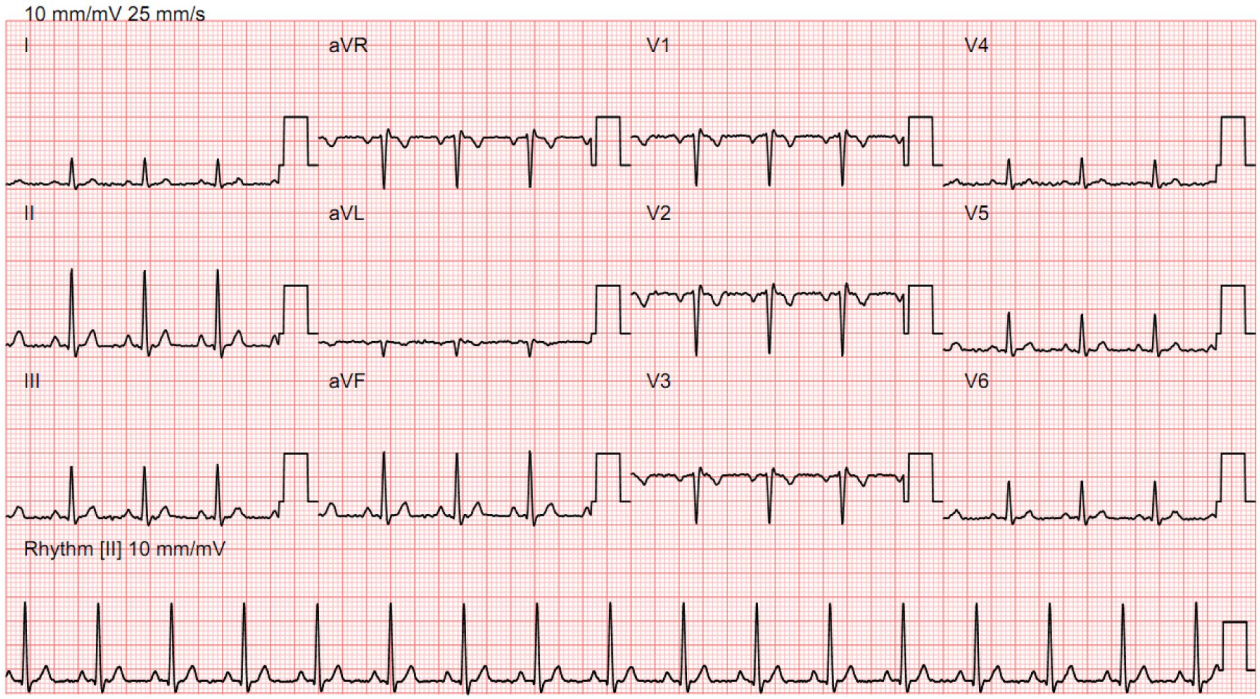
ECG Tracing Correlated to the Cardiac Cycle

https://opentextbc.ca/anatomyandphysiology/chapter/19-2-cardiac-muscle-and-electrical-activity/

ECG leads



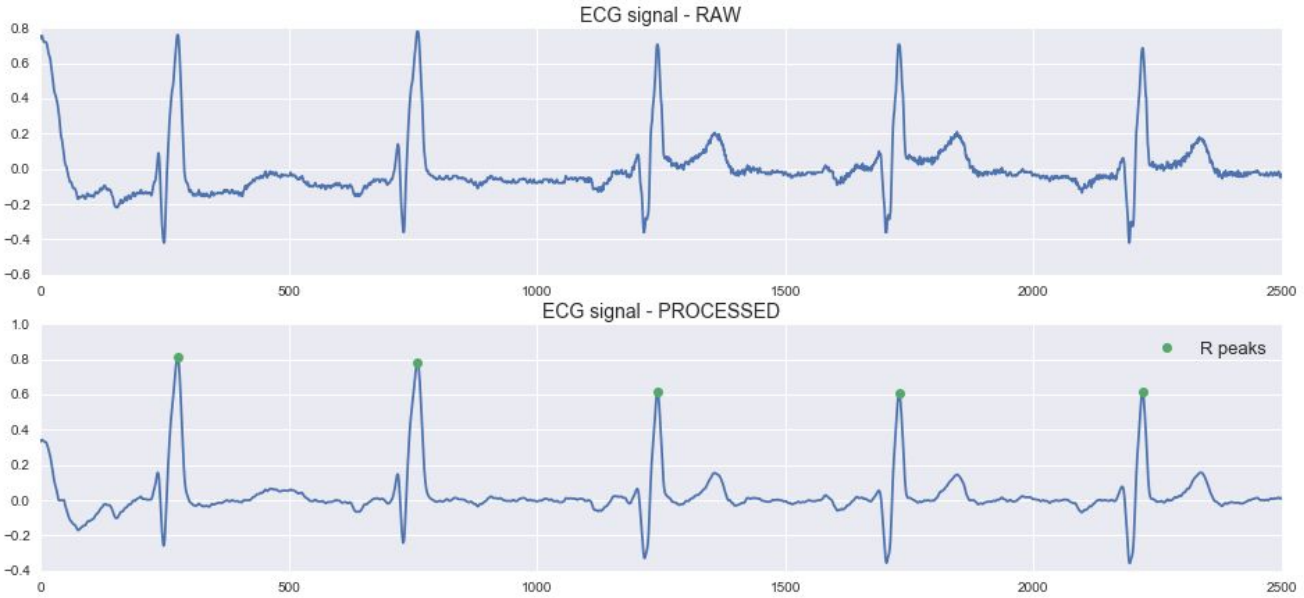
Standard Placement of ECG Leads



https://opentextbc.ca/anatomyandphysiology/wp-content/uploads/sites/142/2016/03/2021_ECG_Placement_of_Electrodes.jpg
http://www.eetimes.com/document.asp?doc_id=1278571

ECG signal processing

1. Low-pass filtering
2. Baseline wander correction
3. R-peak detection using Hamilton segmenter

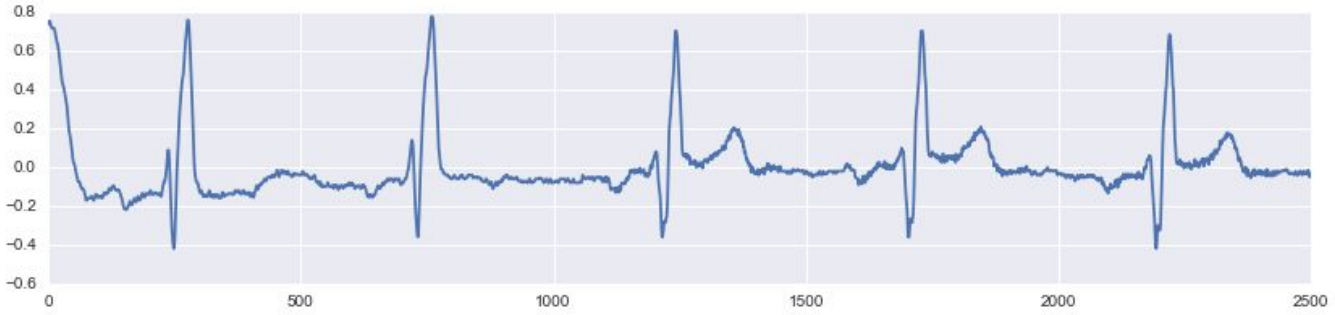


ECG signal quality

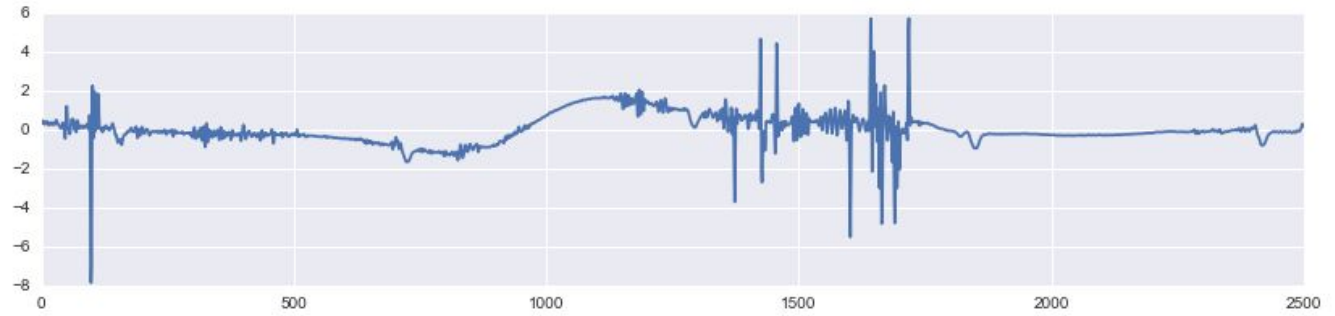
Objective:

To identify acceptable ECG signals to be used for further processing

Good signal



Bad signal



ECG signal quality

Database:

PhysioNet's Computing in Cardiology (CinC) Challenge 2011
Collection of 10-second long ECG signals sampled at 500 Hz
Sample size: "773 *Acceptable"* and 225 "*Not Acceptable*" ECG segments

Features

kurtosis, skewness, energy, relative power, number of R peaks, heart rate, respiration rate, heart rate variability, PCA components of beats, duration of RR interval

Model used:

Nearest Neighbour Classifier: 7-NN, distance-weighted neighbours

https://physionet.org/challenge/2011/

ECG signal quality

Best results:

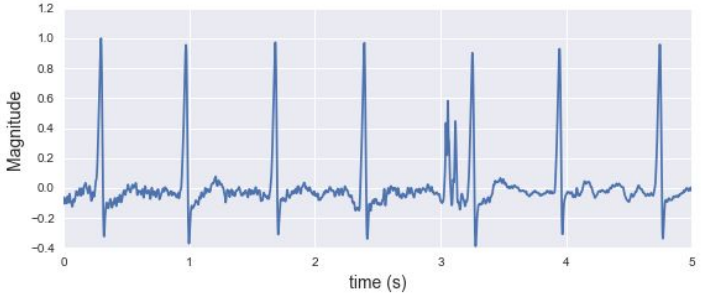
Validation: accuracy - 96.79% , false positive rate - 0%

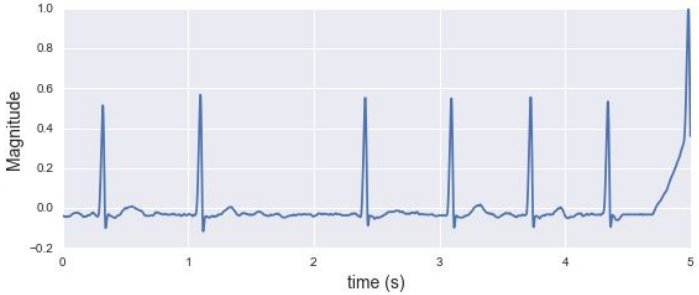
Test: accuracy - 91.89%, false positive rate - 12.61%

Sample results:

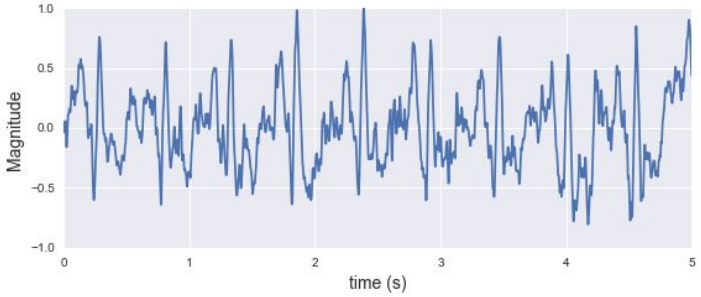
Predicted as Acceptable | *Predicted as Not Acceptable*

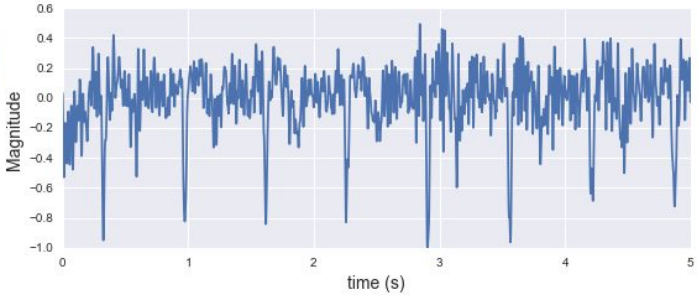
Acceptable





Not Acceptable





What can we do with ECG signals?

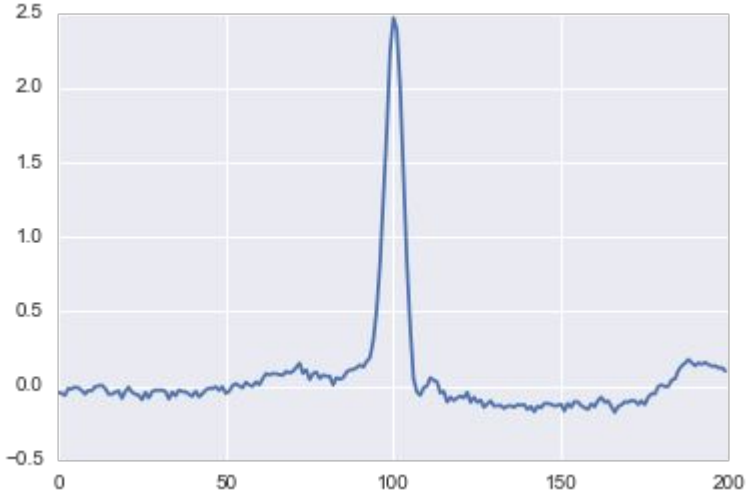
Predict Cardiovascular Diseases (CVDs) using solely a single-lead ECG signal, such as:

1. Atrial Fibrillation (AFIB)
2. Ventricular Fibrillation (VFIB)
3. Bundle Branch Block Beat (BBBB)
4. Premature Atrial Contraction (PAC)
5. Premature Ventricular Contraction (PVC)

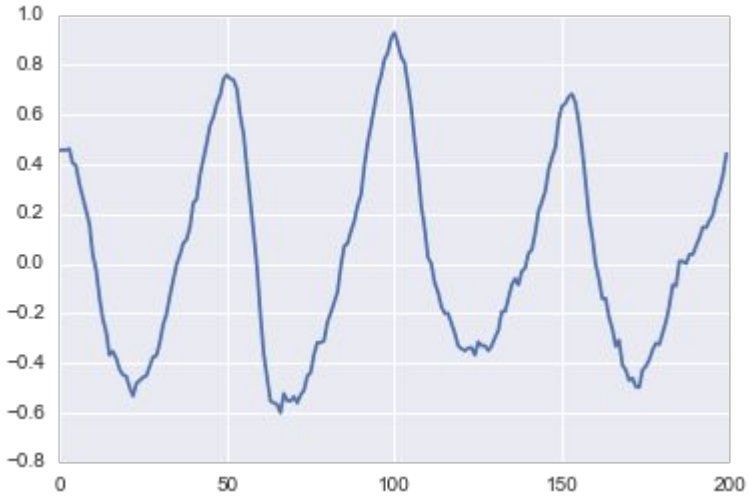
Ventricular Fibrillation

Ventricular fibrillation is *life-threatening*. It is the most serious cardiac rhythm disturbance. The lower chambers quiver and the heart can't pump any blood, causing cardiac arrest.

Non-VFIB Beat



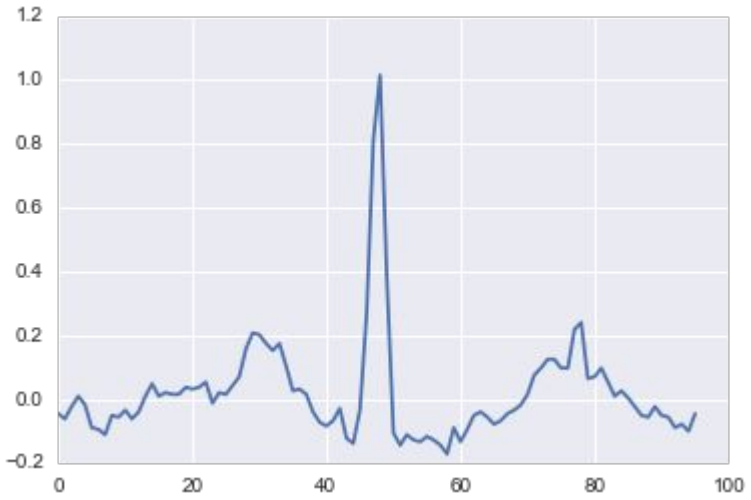
VFIB Beat



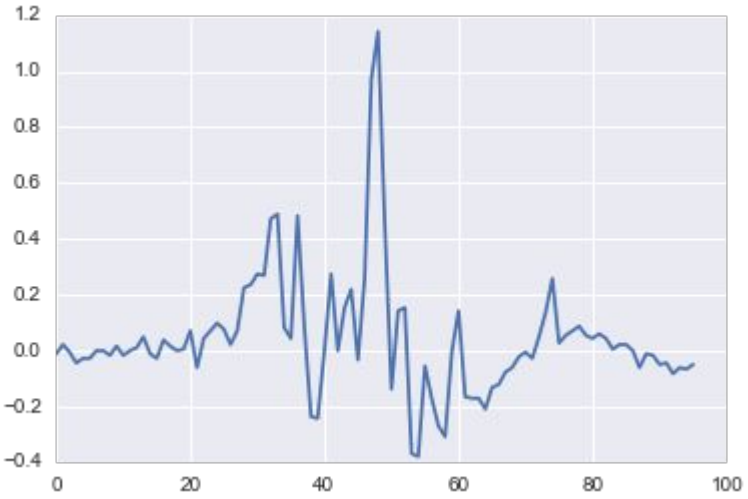
Atrial Fibrillation

The upper chambers of the heart (the atria) beat irregularly (quiver) instead of beating effectively to move blood into the ventricles.

Normal Beat



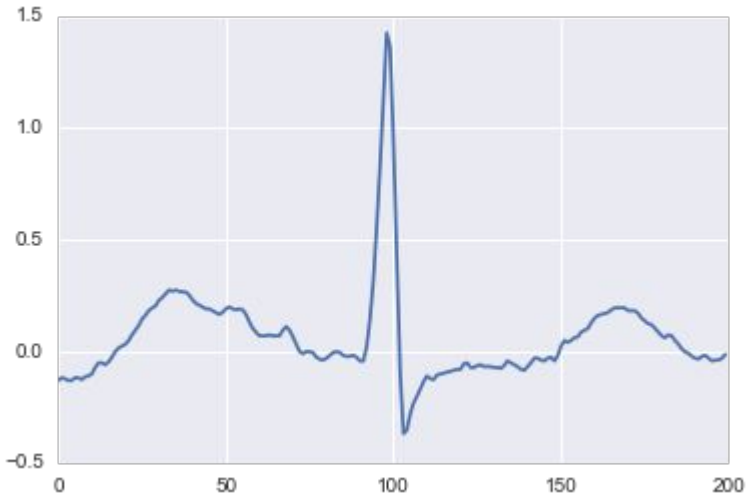
AFIB Beat



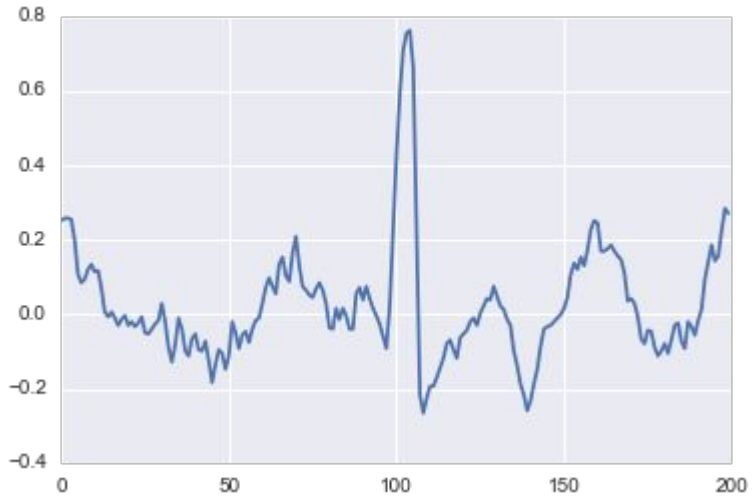
Premature Atrial Contraction

Beats which are initiated in the atria or upper chambers of the heart, prematurely, which cause the SA node (the natural pacemaker of the heart) to be interrupted.

Normal Beat



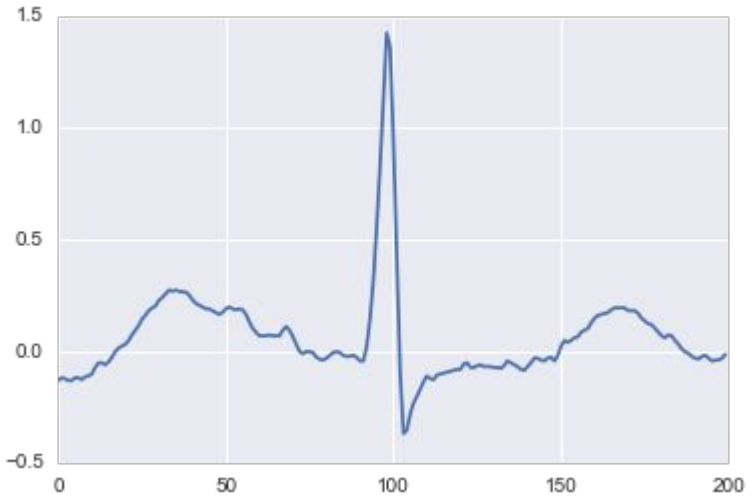
PAC Beat



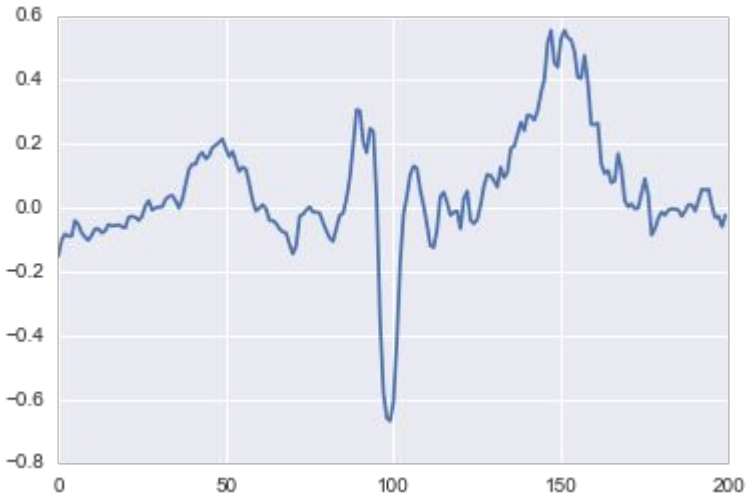
Premature Ventricular Contraction

Beats which are initiated in the ventricles or lower chambers of the heart, prematurely. When the SA node (the natural pacemaker of the heart) gets interrupted, PVCs do not interrupt the SA node. However, with a PVC the ventricles contract, which normally causes the impulse from the atria to be blocked from reaching the ventricles.

Normal Beat



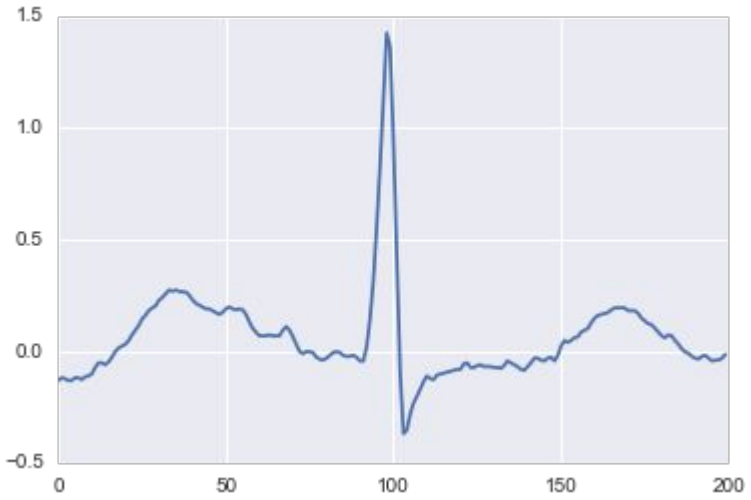
PVC Beat



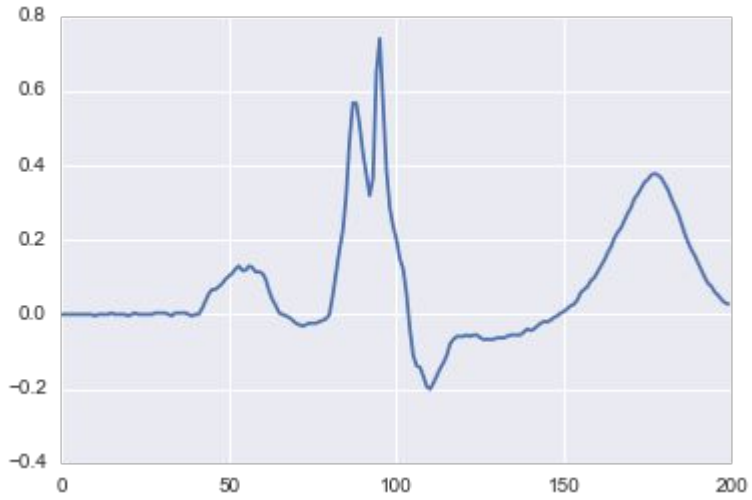
Bundle Branch Block

The QRS is wider than its normal value of .04-.10 seconds and will typically be .12-.16 seconds. In bundle branch block, only one of the ventricles is directly caused to contract by the impulse from the atria. The other ventricle is actually caused to contract by the impulse traveling through the ventricles heart tissue itself. Since this results in one ventricle contracting before the other, the QRS width is increased.

Normal Beat



BBB Beat



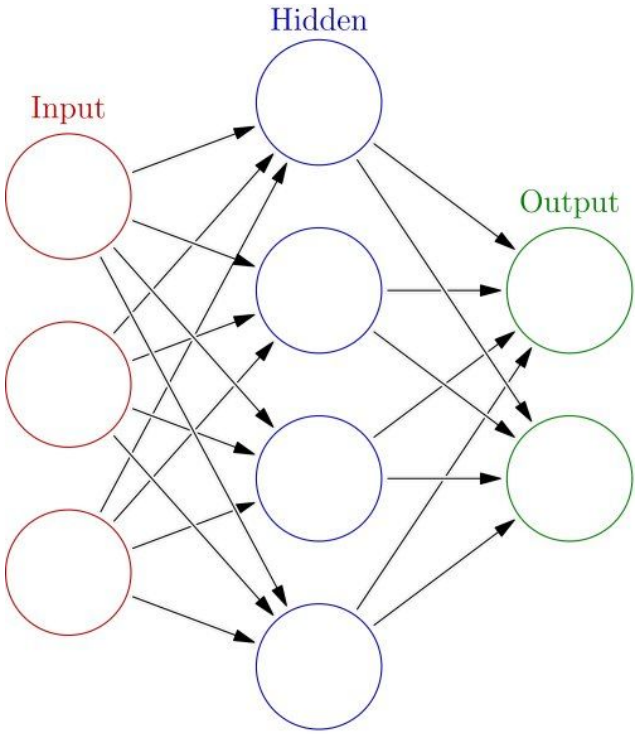
Databases

Databases for supervised learning came from Physionet:

1. St.-Petersburg Institute of Cardiological Technics 12-lead Arrhythmia Database (INCARTDB)
2. Long-term Atrial Fibrillation Database (LTAFDB)
3. Creighton University Ventricular Tachyarrythmia Database (CUDB)

Supervised Learning

Artificial Neural Network is used to train the databases



source:http://www.kdnuggets.com/2016/10/beginners-guide-neural-networks-python-scikit-learn.html

- Beat-level Classification
- MLP Classifier for classifying between classes
- Input feature is the shape of the beat
- Principal Component Analysis is applied on each beat to reduce dimensionality
- Output is the class (CVD, non-CVD)

Results: PAC/PVC/BBBB Classification

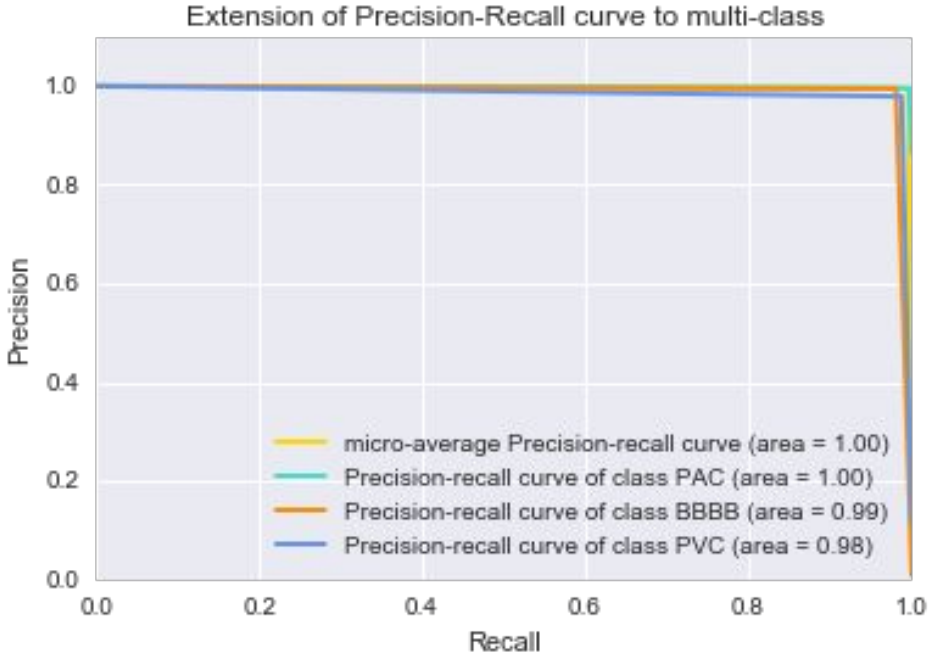
PAC Classification

Sensitivity: When it's actually yes, how often does it predict yes?

83.5 %

Specificity: When it's actually no, how often does it predict no?

99.9 %



Results: PAC/PVC/BBBB Classification

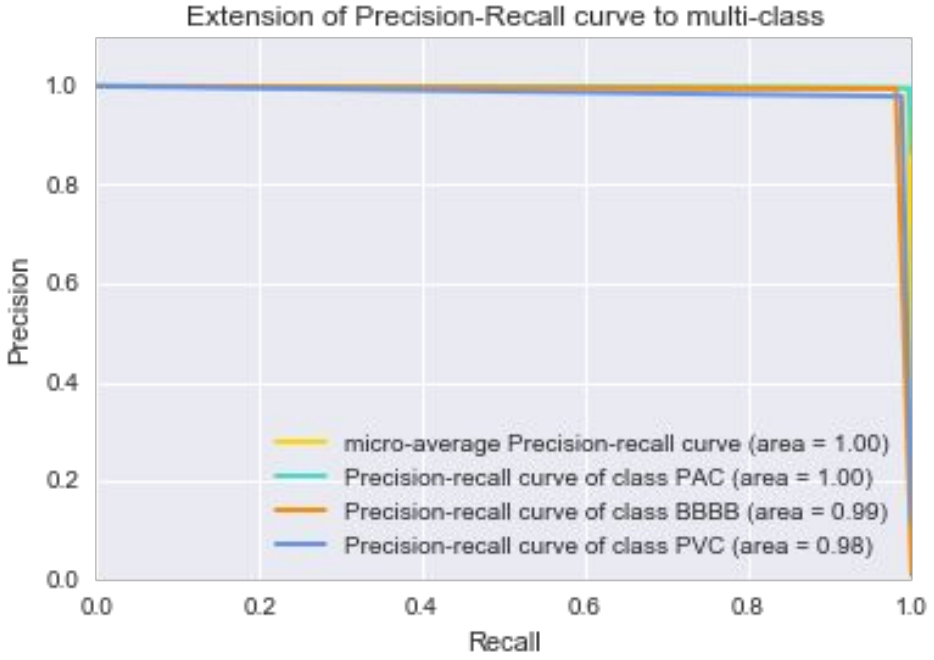
PVC Classification

Sensitivity: When it's actually yes, how often does it predict yes?

98.0 %

Specificity: When it's actually no, how often does it predict no?

99.9 %



Results: PAC/PVC/BBBB Classification

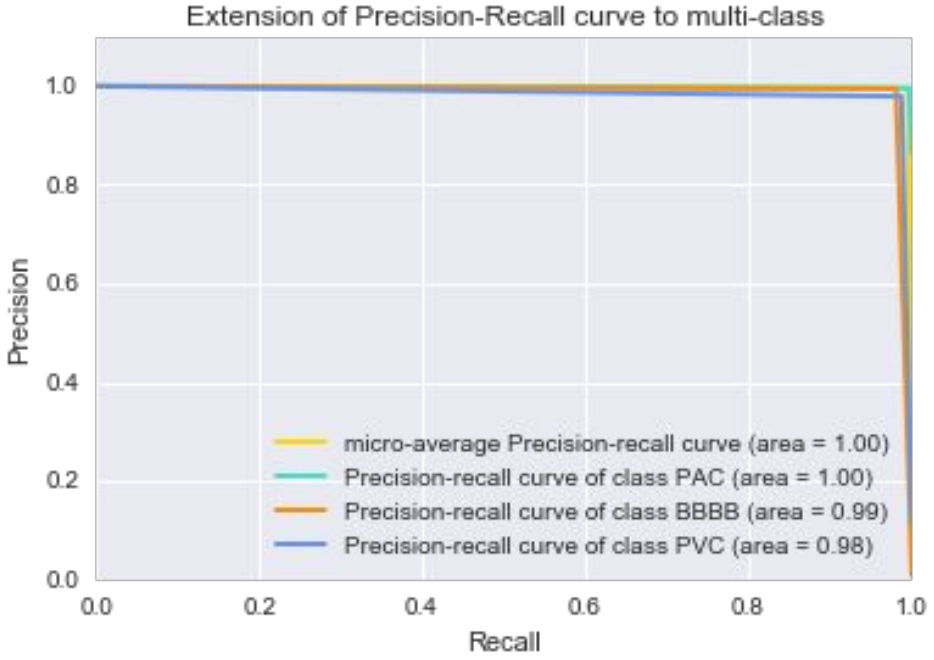
BBBB Classification

Sensitivity: When it's actually yes, how often does it predict yes?

99.7 %

Specificity: When it's actually no, how often does it predict no?

97.7 %



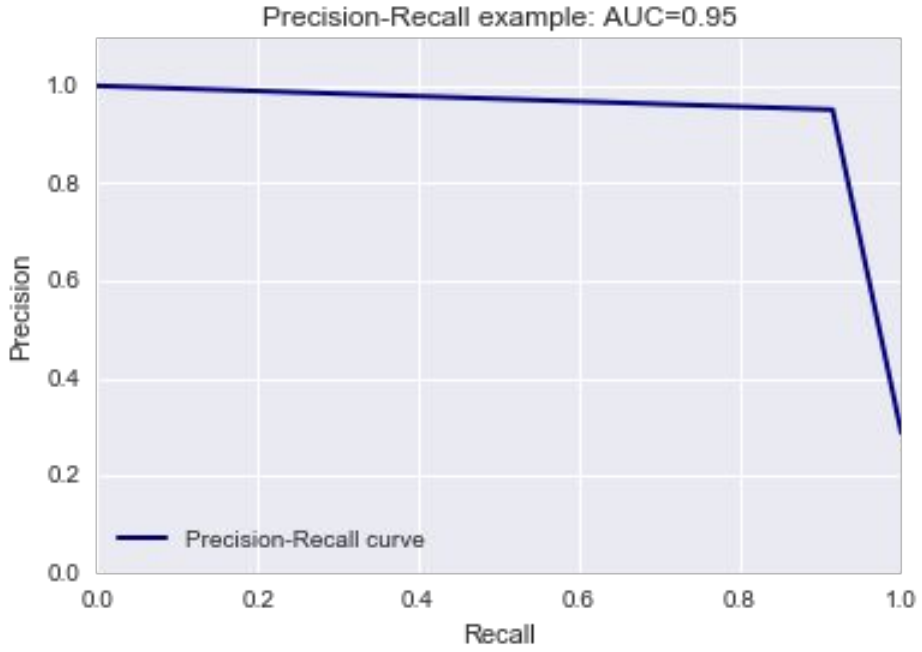
Results: AFIB vs Non-AFIB Beat Classification

Sensitivity: When it's actually yes, how often does it predict yes?

91.5 %

Specificity: When it's actually no, how often does it predict no?

98.1 %



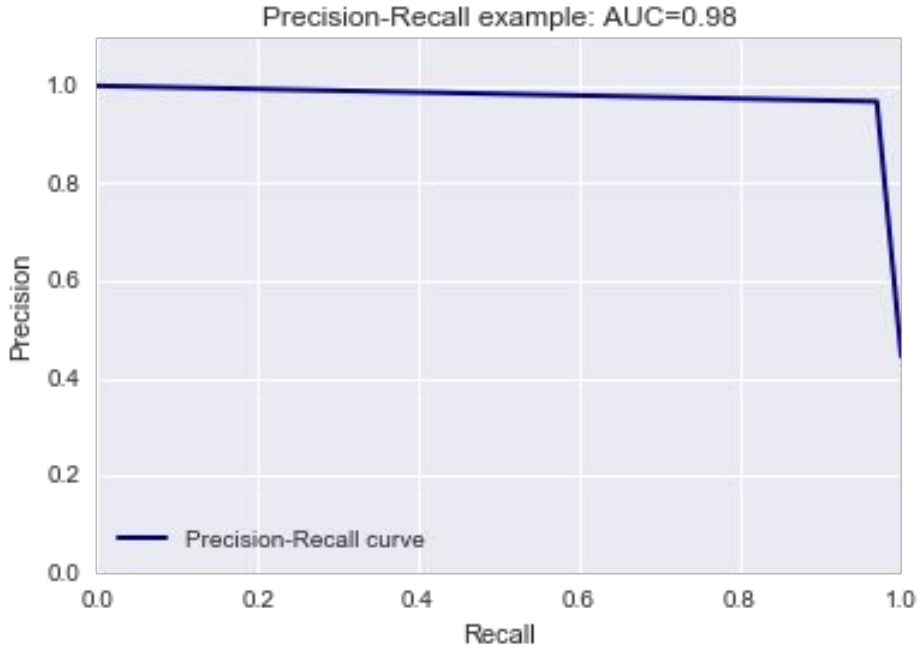
Results: VFIB vs Non-VFIB Beat Classification

Sensitivity: When it's actually yes, how often does it predict yes?

96.9 %

Specificity: When it's actually no, how often does it predict no?

97.4 %



In Summary:

With these models, we can:

Automatically detect, with high accuracy, **Atrial Fibrillation, PAC, PVC, Bundle Branch Block and Ventricular Fibrillation** all from a single-lead ECG.