Biosignal Processing – EEEE 5286
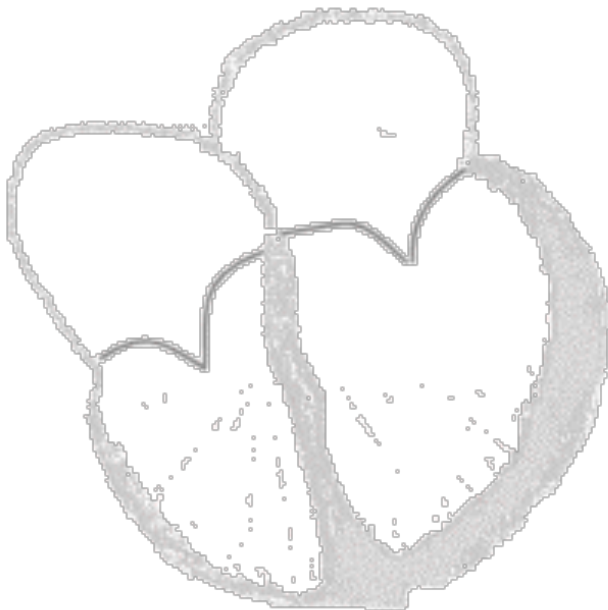## Detection of Atrial Fibrillation from ECG Signals

Lecture by

Prasanth Ganesan

PhD Student, Electrical Engineering
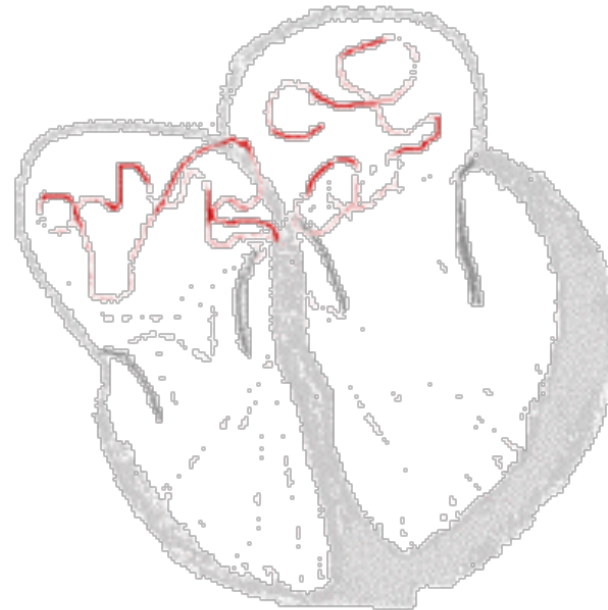
Atrial Fibrillation Review

- Irregular beating of atria
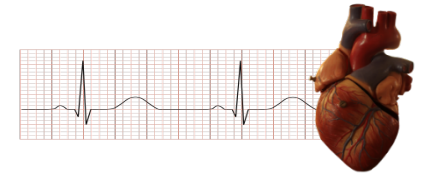- 2.7 million Americans and 30 million worldwide affected every year
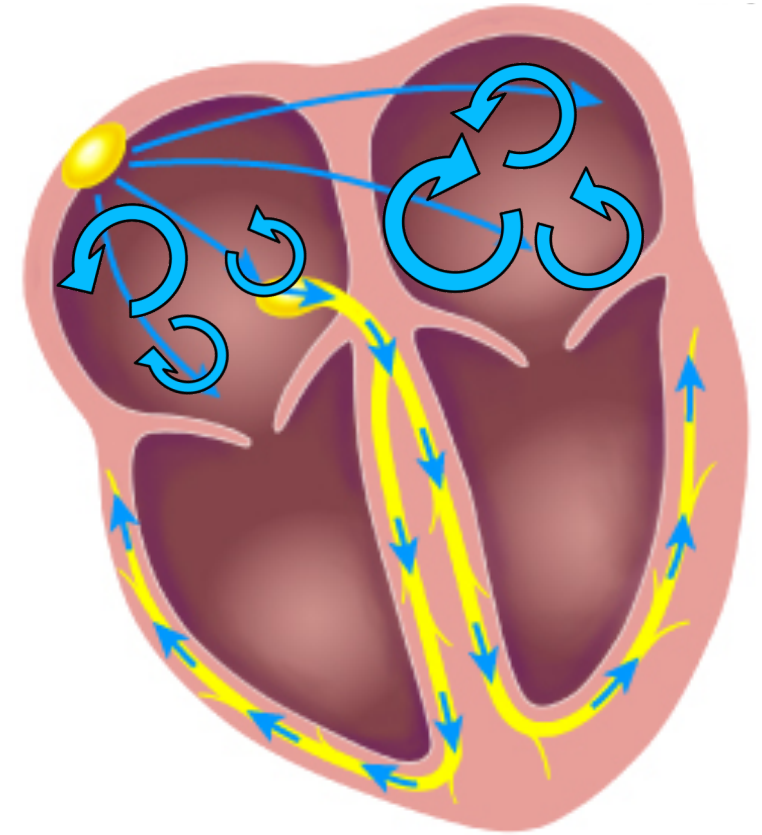
Normal heart beat

Atrial fibrillation

Causes of Atrial Fibrillation

- Re-entry – Signals enters back to the atrium without leaving the chamber.

- Single fibrillatory reentry

- Multiple randomly propagating reentries
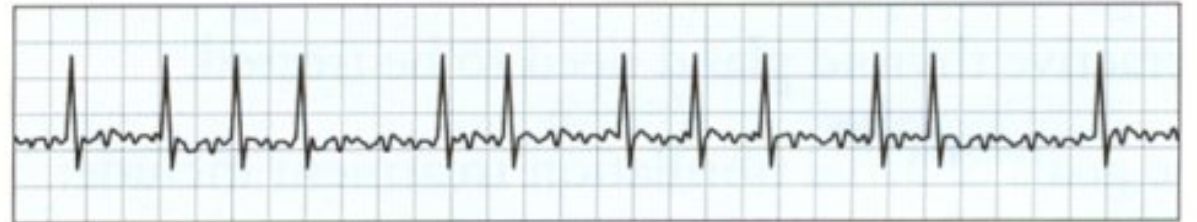
- Abnormal focal activity

AF Signal Characteristics

- Normal ECG – PQRST

- AF ECG:
  - No p-waves
  - Random QRS waves
  - No isoelectric line
  - High "heart rate"
  - Fibrillatory waves

ECG tracing of a normal heart rhythm.

In atrial fibrillation, the tracing shows tiny, irregular "fibrillation" waves between heartbeats. The rhythm is irregular and erratic.

Methods of Detection

- Time domain methods
    - R-R interval
    - Heart rate variability features such as mean heart rate, mean R-R intervals, standard deviation of the intervals etc.
- Frequency domain methods
    - FFT of ECG
    - Frequency features in different bands
- Time-frequency Analysis
    - Spectrogram:
        - Stridh, Martin, et al. "Characterization of atrial fibrillation using the surface ECG: time-dependent spectral properties." *IEEE transactions on Biomedical Engineering* 48.1 (2001): 19-27.
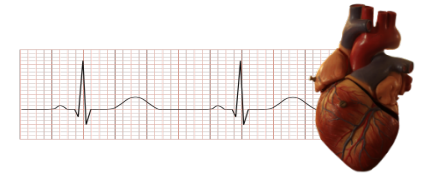
Methods of Detection

- Linear and Non-linear analysis
  - Regression based methods
  - Bayesian decision methods
  - Non-stationary data analysis

- Machine learning methods
  - Train a classifier based on training features
    - Ladavich, Steven, and Behnaz Ghoraani. "Rate-independent detection of atrial fibrillation by statistical modeling of atrial activity." *Biomedical Signal Processing and Control* 18 (2015): 274-281.
    - Li, Qiao, Cadathur Rajagopalan, and Gari D. Clifford. "Ventricular fibrillation and tachycardia classification using a machine learning approach." *IEEE Transactions on Biomedical Engineering* 61.6 (2014): 1607-1613.

- Hybrid methods
  - Huang, Z., Y. Chen, and M. Pan. "Time-frequency characterization of atrial fibrillation from surface ECG based on Hilbert-Huang transform." *Journal of medical engineering & technology* 31.5 (2007): 381-389.
  - Arafat, Muhammad Abdullah, Jubair Sieed, and Md Kamrul Hasan. "Detection of ventricular fibrillation using empirical mode decomposition and Bayes decision theory." *Computers in Biology and Medicine* 39.11 (2009): 1051-1057.

- Review of some methods
  - Ganesan, Prasanth, et al. "Computer-Aided Clinical Decision Support Systems for Atrial Fibrillation." *Computer-aided Technologies-Applications in Engineering and Medicine*. InTech, 2016.

Today's Topic of Discussion

- AF detection by feature extraction in EMD domain using IMFs:
  - Maji, U., M. Mitra, and S. Pal. "Automatic detection of atrial fibrillation using empirical mode decomposition and statistical approach." *Procedia Technology* 10 (2013): 45-52.
  - Paper URL: http://www.sciencedirect.com/science/article/pii/S2212017313004891

Method Used In The Article

Input filtered NSR ECG → Choose one cycle → Apply EMD → Get all the IMFs → Repeat for filtered AF signal → Find the best IMF that distinguishes AF signals → Compute statistics of IMFs and compare the statistics

Matlab Example - Physiobank
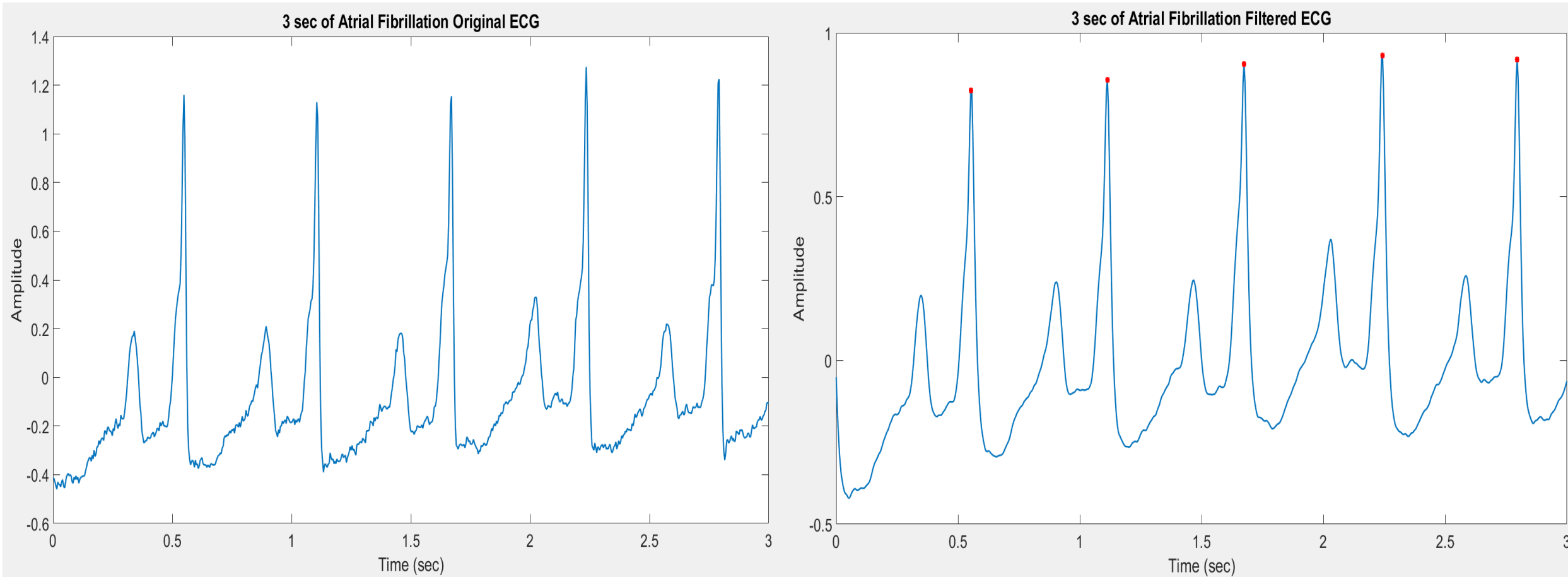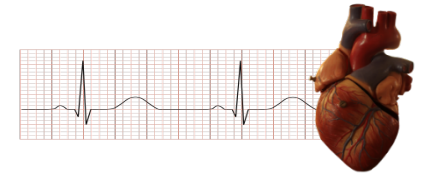
- Physiobank afib database - https://physionet.org/physiobank/database/afdb/

- Import the ECGs

- Preprocessing for noise removal
  - Butterworth band pass filter of pass band frequency 0.5Hz to 45Hz

- 102 different cycles of NSR signals

- 63 different cycles for AF signals
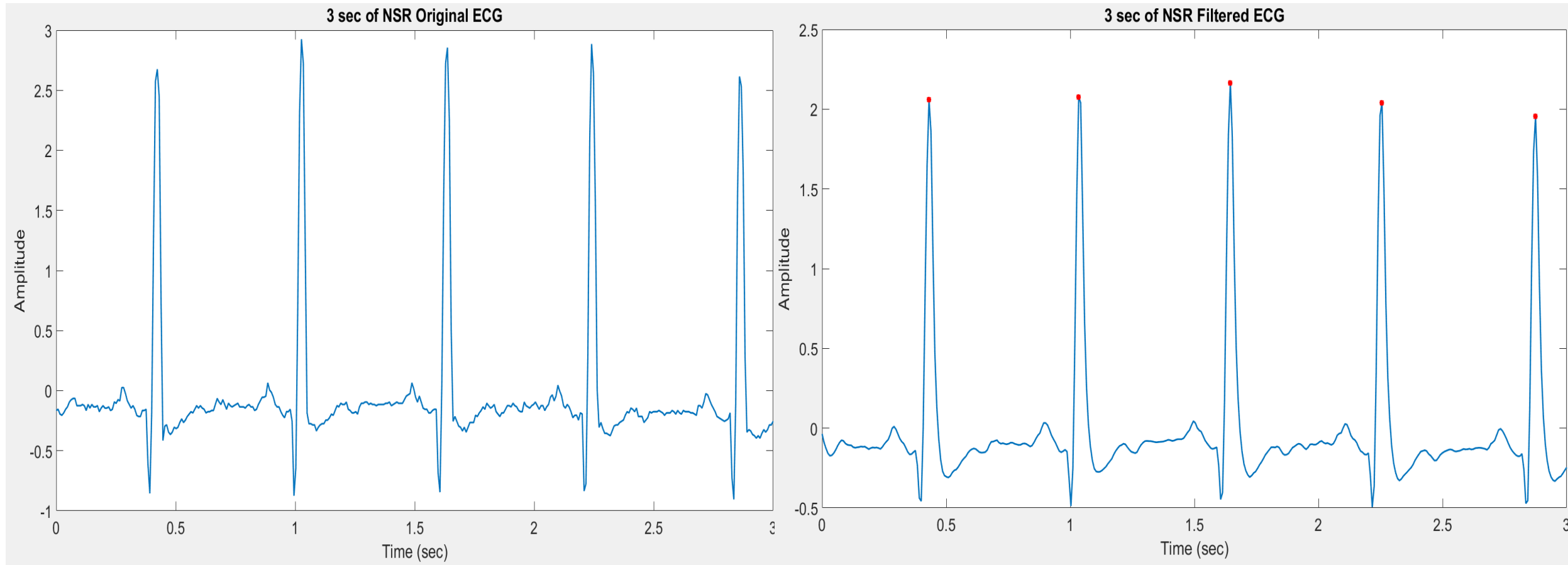
Matlab Code Sections

- Import ECGs

- Preprocessing

- Choose cycles
  - Annotate based on visual thresholds
  - Choose R-R cycle

- Apply EMD

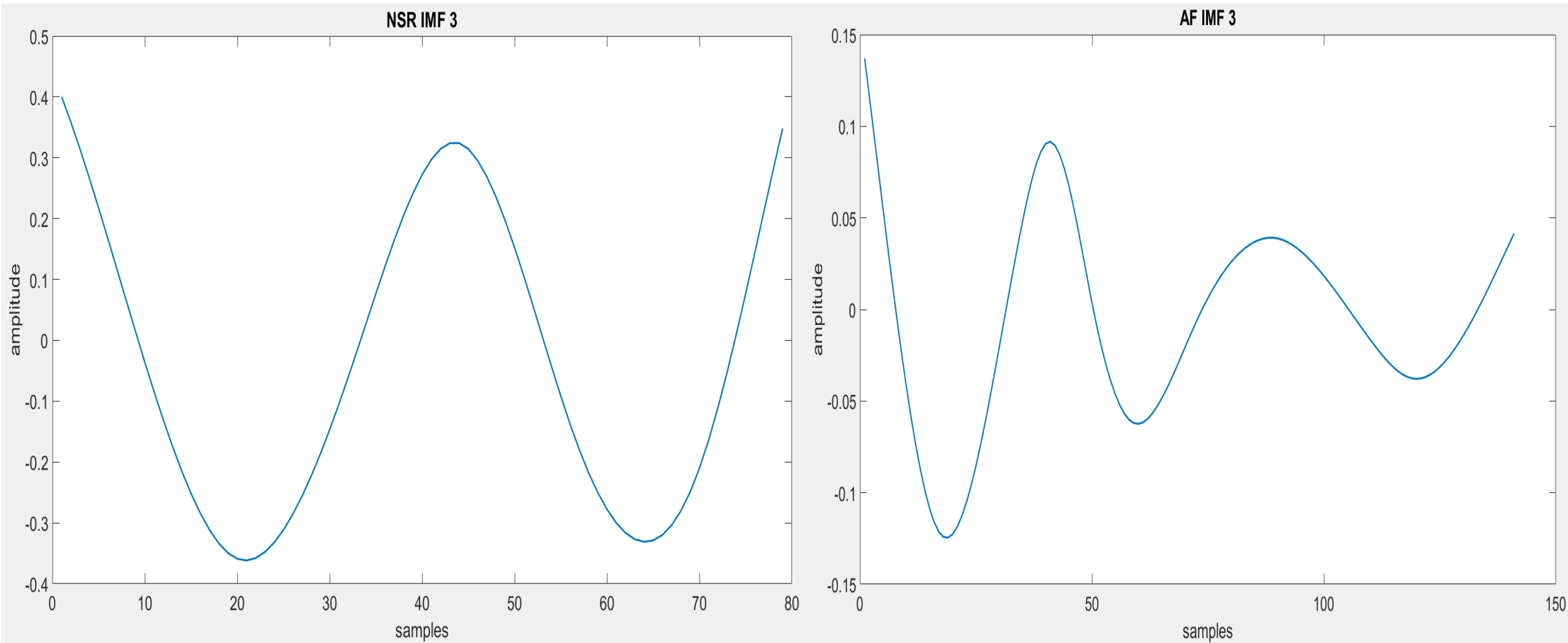- Compute statistics of IMFs
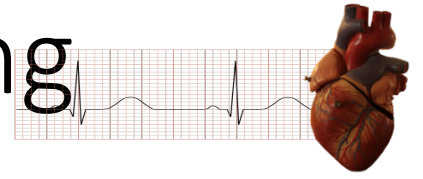
- Compare the statistics of AF vs NSR
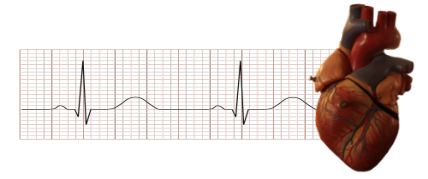
AF ECG before and after filtering

3 sec of Atrial Fibrillation Original ECG

3 sec of Atrial Fibrillation Filtered ECG

NSR ECG before and after filtering

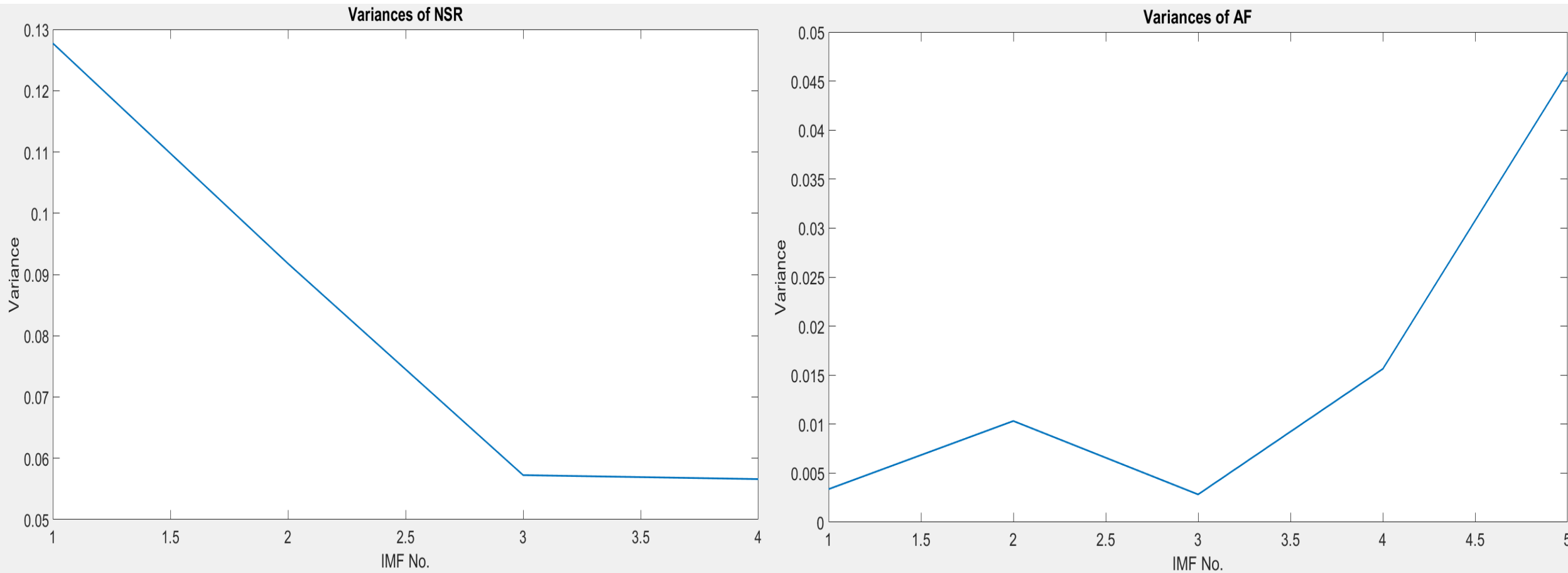3 sec of NSR Original ECG

3 sec of NSR Filtered ECG

IMF 3 of NSR vs AF – Note the decreasing amplitude of AF

Variances of NSR IMFs vs AF IMFs

- Variances of NSR decreases with increasing IMF, whereas it increases for AF.
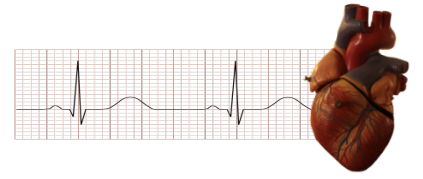
Final Detection Steps

- Compute different statistics

- These are your features

- Provide these features to train a classifier – could be linear regression, non-linear classifiers, semi-supervised classifiers etc.

- AF detection percentage success can be compared using test data

Conclusion

- IMFs are highly useful for feature extraction
- EMD domain analysis is a notable domain to explore just as the Fourier domain and others
- They are helpful in detection of abnormal rhythms.