Arrhythmia signatures with empirical mode decomposition

Ashwin Sundar

Mentors: Dr. Jeffrey La Belle, Dr. Mark Spano, and Dr. Heather Ross

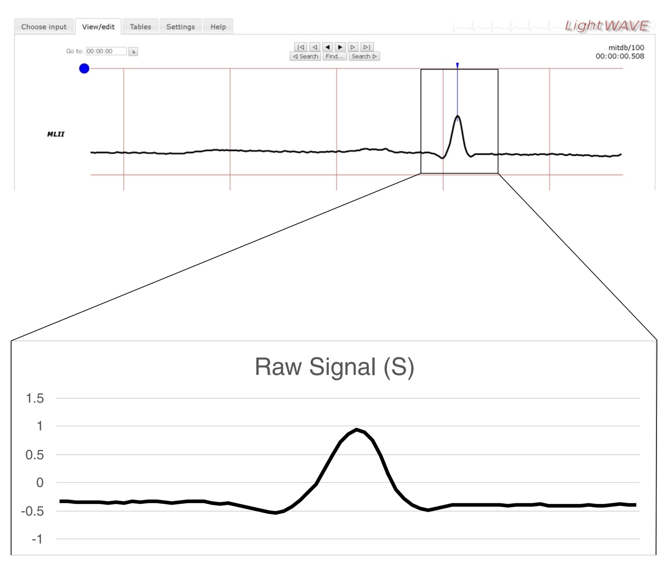
IRA A. FULTON SCHOOLS OF engineering
ARIZONA STATE UNIVERSITY

Abstract

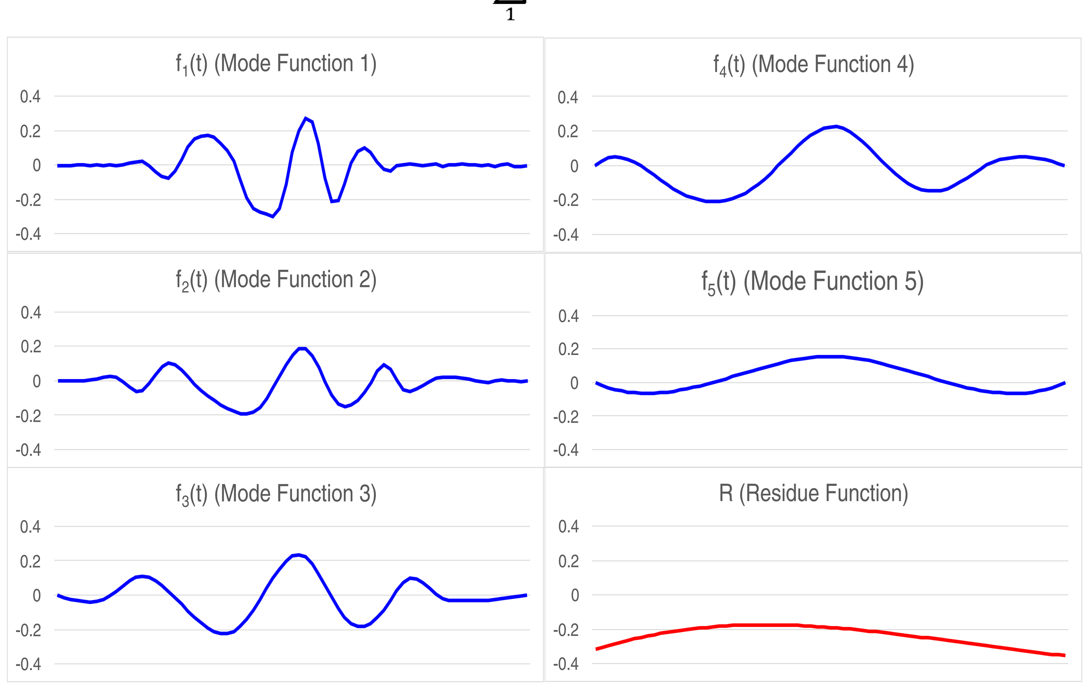
- Physiological signals tend to be short, nonlinear, and nonstationary; time-frequency analysis is not always suitable
- Empirical mode decomposition (EMD) is intuitive and stays in the time domain
- ECG signals of select cardiac conditions were windowed, decomposed, and averaged to create average mode functions
- Signal differences between conditions were calculated, which can be used to create unique signatures for each signal

Methods

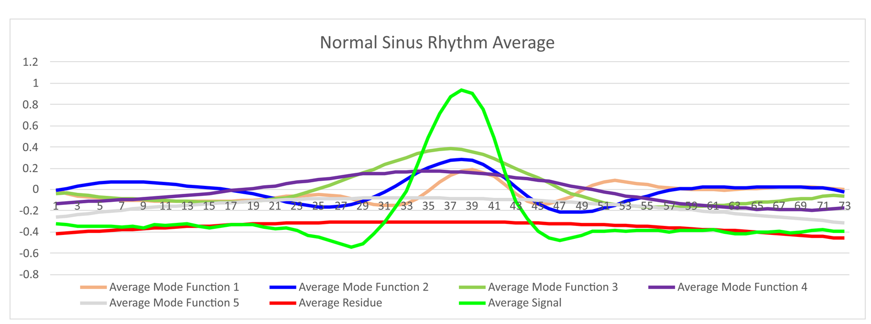
Identify window → Decompose → Calculate signatures



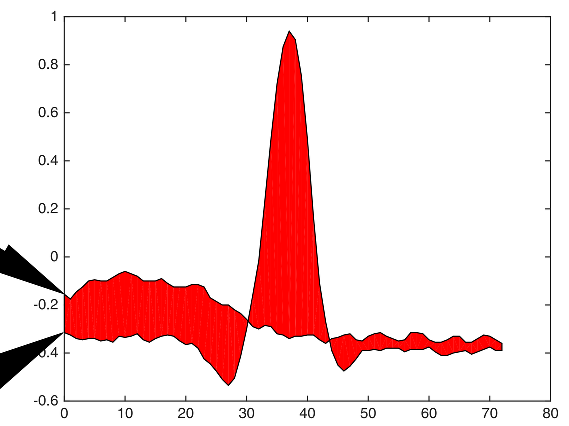
$$S = \sum_{1}^{m} f_m(t) + R$$



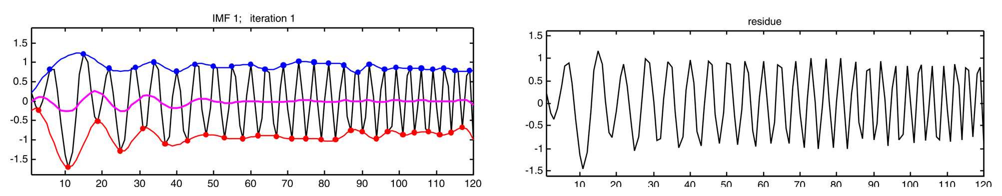
$$A_k = \frac{1}{n}\sum_{1}^{n} f_{nk}(t)$$



RMS deviation



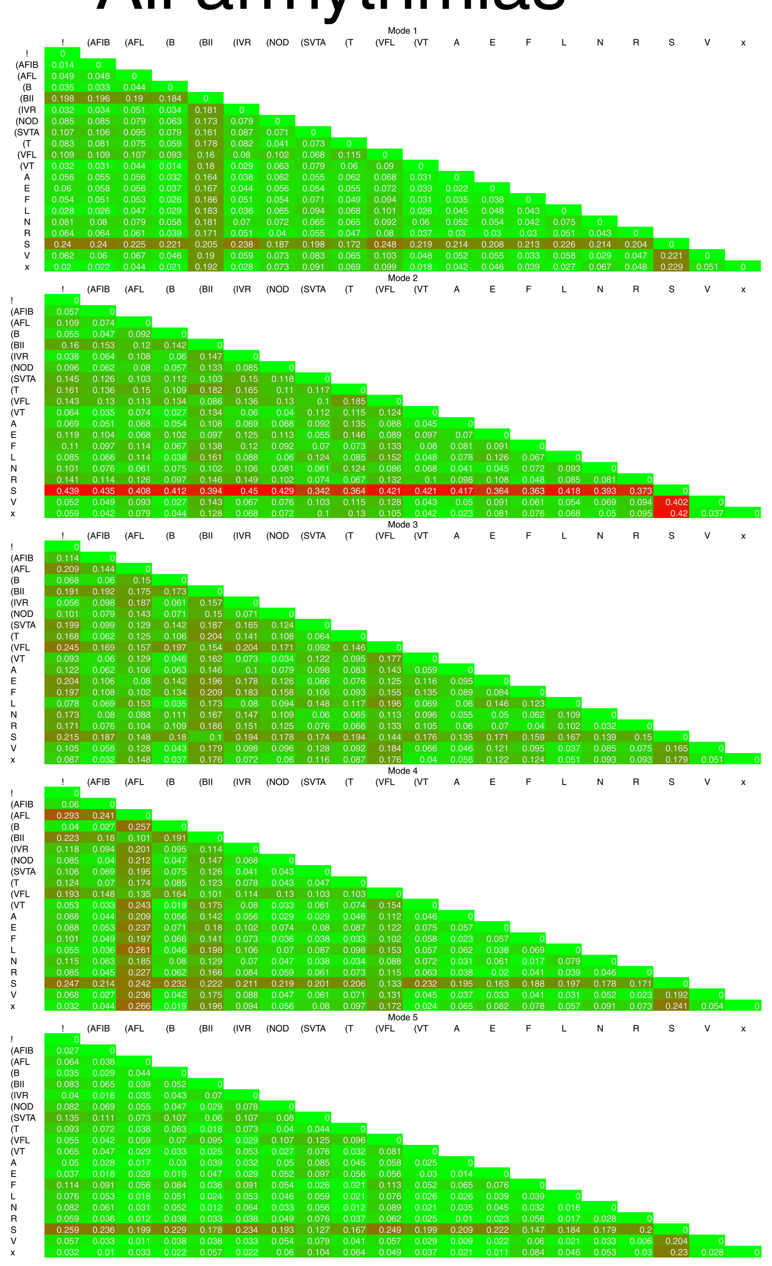
Cubic-spline interpolation



Results

RMS Deviations

All arrhythmias



Highlighted arrhythmias

Mode 1

	(B	A	F	N	V
(B	0				
A	0.032	0			
F	0.026	0.035	0		
N	0.058	0.052	0.042	0	
V	0.046	0.052	0.033	0.029	0

Mode 2

	(B	A	F	N	V
(B	0				
A	0.054	0			
F	0.067	0.081	0		
N	0.075	0.041	0.072	0	
V	0.027	0.05	0.061	0.069	0

Mode 3

	(B	A	F	N	V
(B	0				
A	0.063	0			
F	0.134	0.089	0		
N	0.111	0.055	0.062	0	
V	0.043	0.046	0.095	0.085	0

Mode 4

	(B	A	F	N	V
(B	0				
A	0.056	0			
F	0.066	0.023	0		
N	0.08	0.031	0.017	0	
V	0.042	0.037	0.041	0.052	0

Mode 5

	(B	A	F	N	V
(B	0				
A	0.03	0			
F	0.084	0.065	0		
N	0.052	0.035	0.032	0	
V	0.038	0.009	0.06	0.033	0

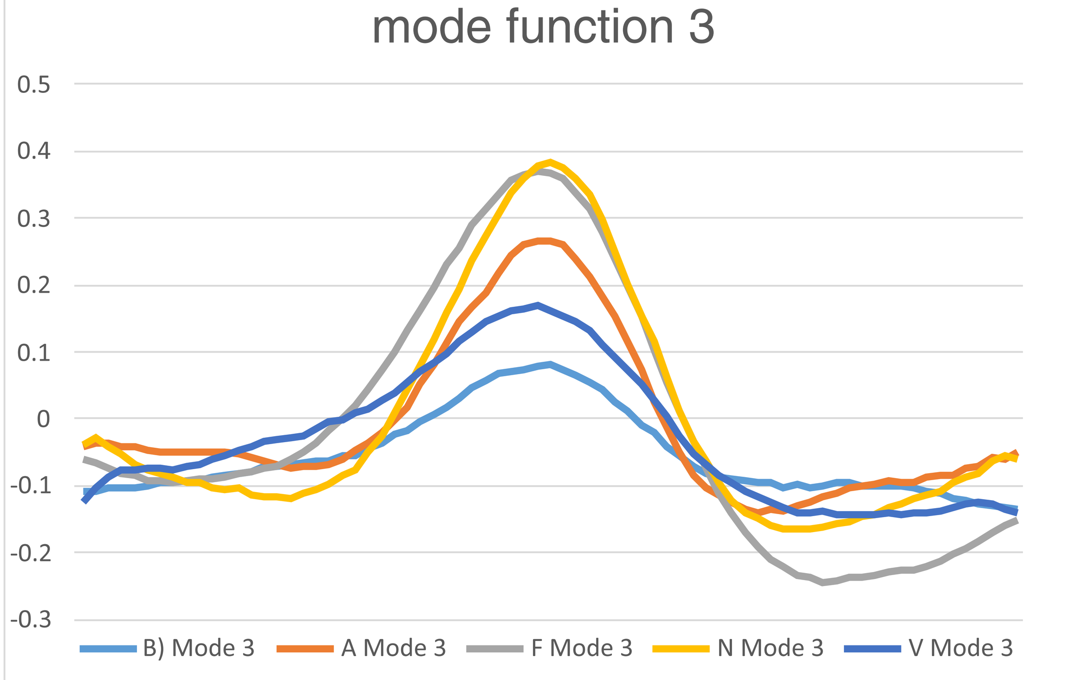
Residue

	(B	A	F	N	V
(B	0				
A	0.022	0			
F	0.018	0.017	0		
N	0.016	0.009	0.019	0	
V	0.042	0.033	0.025	0.039	0

Symbol	Meaning	# of patient records	# of data sets
!	Ventricular flutter wave	1	42
(AFIB	Atrial fibrillation	7	78
(AFL	Atrial flutter	3	36
(B	Ventricular bigeminy	13	171
(BII	2° heart block	1	5
(IVR	Idioventricular rhythm	2	4
(NOD	Nodal (A-V junctional) rhythm	3	7
(SVTA	Supraventricular tachyarrhythmia	7	26
(T	Ventricular trigeminy	12	77
(VFL	Ventricular flutter	1	6
(VT	Ventricular tachycardia	12	54
A	Atrial premature beat	27	319
E	Ventricular escape beat	2	30
F	Fusion of ventricular and normal beat	17	136
L	Left bundle branch block beat	4	82
N	Normal sinus rhythm	38	397
R	Right bundle branch block beat	6	132
S	Supraventricular premature beat	1	2
V	Premature ventricular contraction	36	593
x	Non-conducted P-wave (blocked APB)	5	86

Data source: MIT-BIH Arrhythmia Database

Comparison of select ECG signals, mode function 3



Discussion

- EMD tends to segregate noise into early modes, and baseline drift into later modes
- Mode function 3 seems to differentiate signals the most effectively

Broader Impacts

- Easy to implement in a low-power environment, where Fourier transforms are difficult to calculate
- Signatures could be used to identify artifacts without relying on physician annotations
- Future work could focus on calculating inter- and intra-patient signal stability with EMD

References

Huang, N. E., Shen, Z., Long et al. (1998). The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis. Proceedings of the Royal Society, 903-995.

Rilling, G. (2007). Empirical Mode Decomposition. Retrieved from http://perso.ens-lyon.fr/patrick.flandrin/emd.html

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