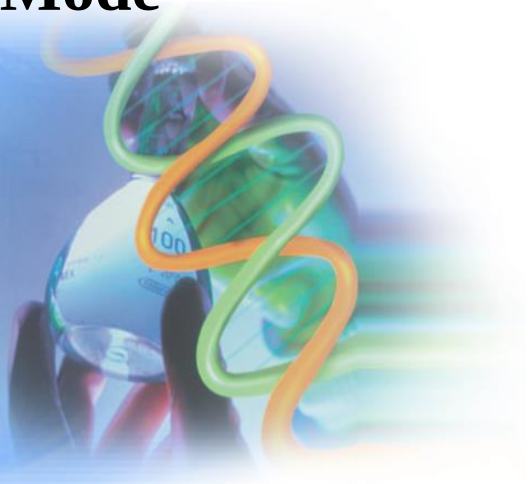
Electrocardiography Signal Decomposition Using a Novel Modulated Ensemble Empirical Mode Decomposition Method

Chun-Hsiang Huang, *Po-Hsun Huang, and Tzu-Chien Hsiao*



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Curriculum vitae

➢ *Educational experience*

- 2013/09-2017/06: Department of Computer Science, College of CS , NCTU (GPA 3.38)
- 2017/07- now : Institute of Biomedical Engineering, College of ECE, NCTU (GPA 4.0)

➢ *Programming skill*

- Intermediate: LabVIEW, C/C++, PHP, ExtJS, MySQL, MATLAB, etc.
- Basic: Python, Haskell, etc.

➢ *Working experience*

- 2015/08- now: Hermes-Epitek IT. (Part-time on IT Division)(漢民科技)

➢ *Certificate*

- 2017/04/25 Certified LabVIEW Associate Developer (CLAD, 100-317-19069)
- 2017/12/29 Certified LabVIEW Developer (CLD, 100-918-10039)

Personal photo

Outline

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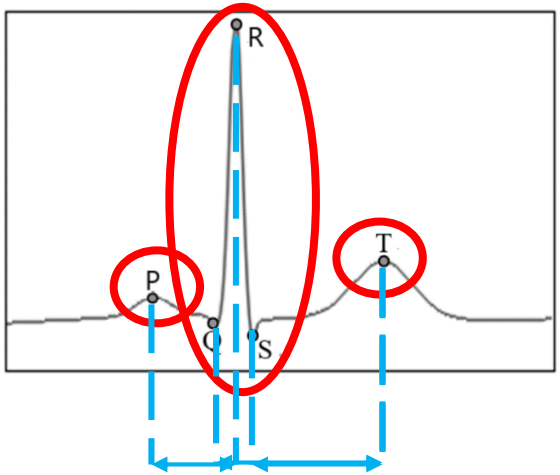
Electrocardiography (ECG)

- **Electrocardiography (ECG) is an important test in the diagnosis of heart disease,**
- **ECG usually consists of several waveforms, such as P wave, QRS-complex, and T wave.**

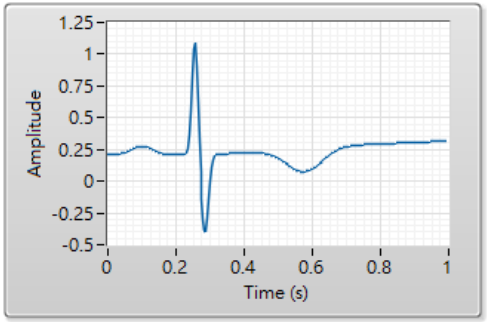
Feature	description
P wave	Depolarization of the atria
QRS complex	Depolarization of the right and left ventricles
T wave	Ventricular repolarization
PR interval	Duration of the impulse from the sinus node to the atrioventricular node
ST segment	Period of ventricles depolarization
QT interval	The beginning of the QRS complex to the end of the T wave



T wave in heart disease

- **Many diseases are diagnosed by T wave's feature. For example, T-wave inversion, biphasic T-wave, T-wave alternans, etc.**

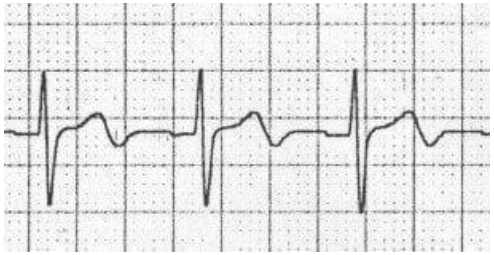
▪ T-wave inversion



generated by LabVIEW "Simulate ECG"

Hypokalemia

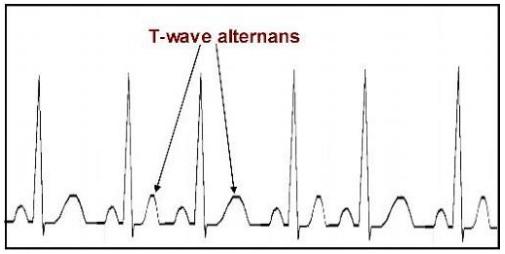
▪ biphasic T-wave



https://litfl.com/t-wave-ecg-library/

associating with myocardial ischaemia and hypokalaemia

▪T-wave alternans

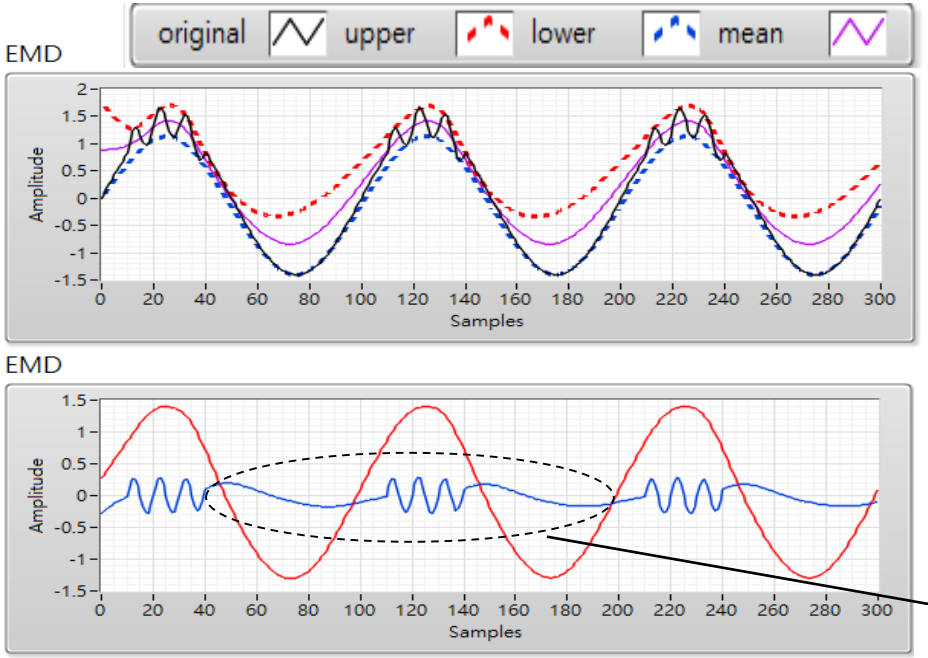


http://www.washingtonhra.com/ekg-monitoring/t-wave-alternans-mtwa.php

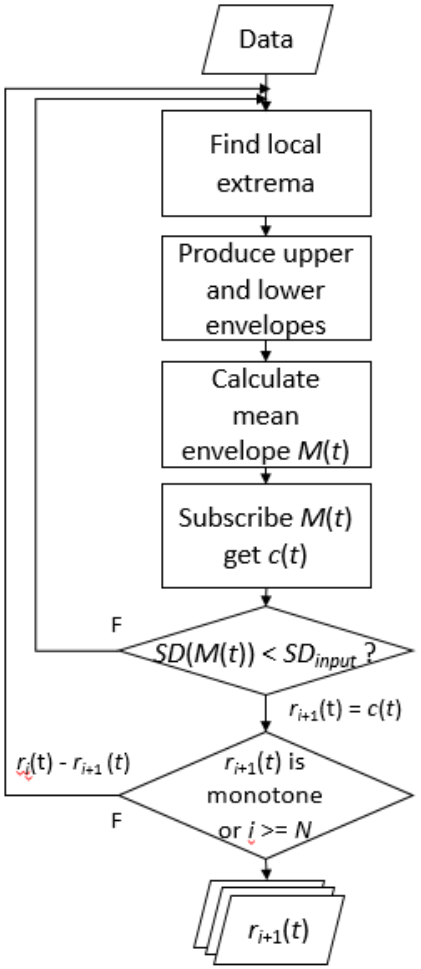
associating with ventricular arrhythmias and sudden death

ECG decomposing and features extracting

- **Detect by amplitude, spacing, and location**
  - susceptible to noise
  - vulnerable to respiratory fluctuations
- **Wavelet transform**
  - not adaptive
  - mother wavelet will limit the performance of the wavelet analysis
- **Empirical Mode Decomposition (EMD)**
  - mode mixing problem



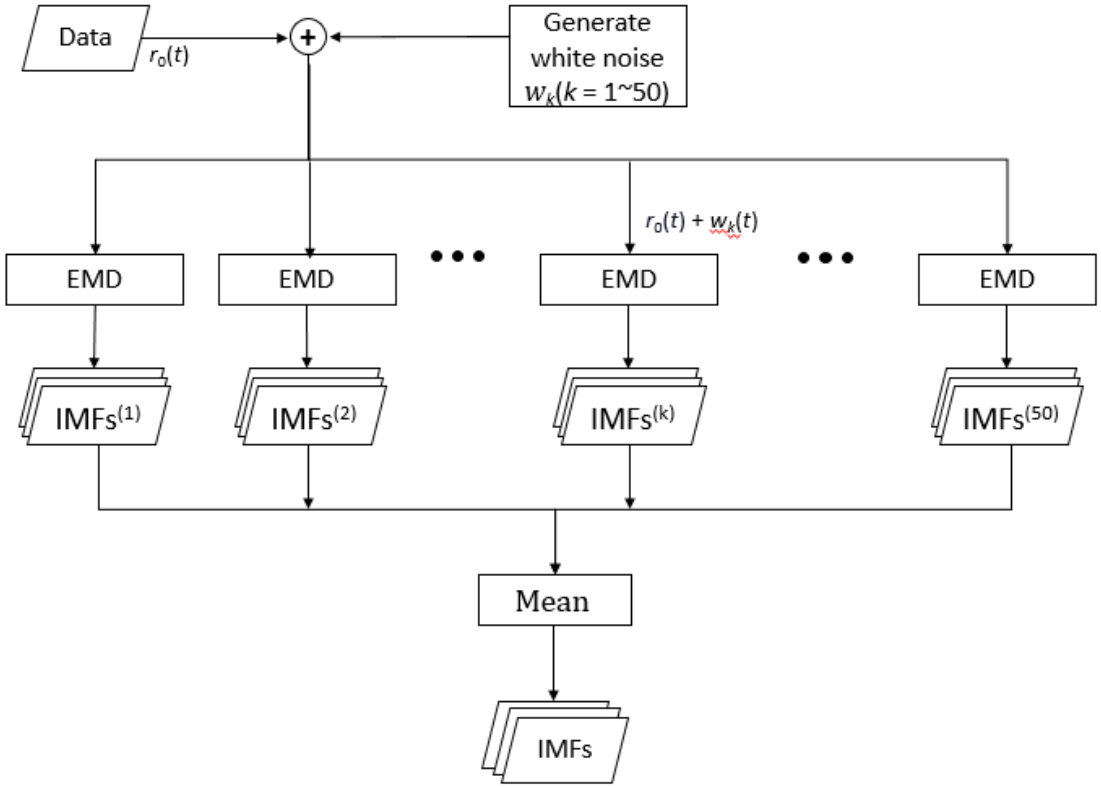
Mode mixing



EMD algorithm

Ensemble Empirical Mode Decomposition (EEMD)

- **Adding noise into signal to solve the mode mixing problem**
- **The noise added in EEMD may remain in Intrinsic Mode Functions (IMFs) and cause reconstruction error**



EEMD algorithm

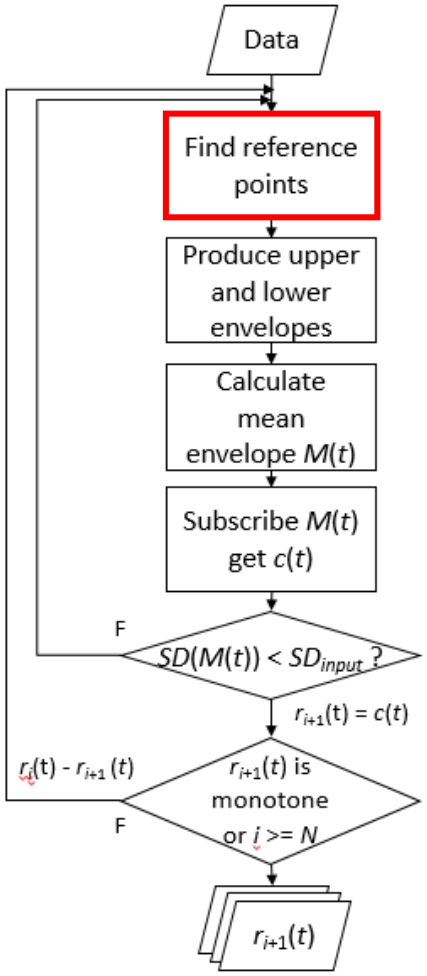
Motivation and objective

- **When using EMD to decompose ECG, it is easy to have mode mixing problems.**
- **Using EEMD can avoid mode mixing problems, but will cause noise to remain in the ECG.**
- **T wave is an important feature which is associated with many disease.**

- **In this study, we propose a new method based on EMD and EEMD. The new method will not add noise to the original signal, but can solve mode mixing problem and decompose T wave.**

Modulated EEMD

- **The Gaussian white noise will only assist to get the reference points which is treated as the extrema points.**
- **The modified part will solve the mode mixing problem and avoid adding external noise into the ECG signal.**



Modulated EMD algorithm

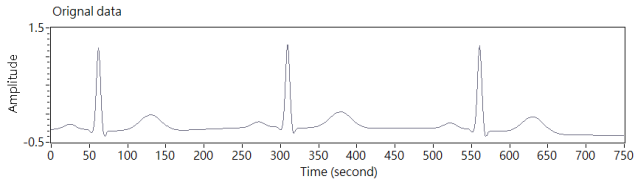
Testing data

➢ Simulated ECG

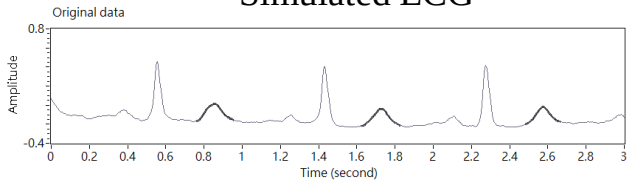
- generated by LabVIEW “Simulate ECG”

➢ PhysioNet QT database ECG

- Fs: 250 Hz
- T-wave labeling
- totally 105 records



Simulated ECG



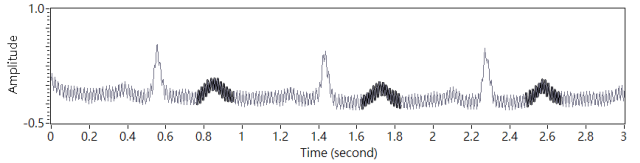
PhysioNet QT database ECG

Database	MIT-BIH						ESC
	Arrhythmia	ST change	Supraventricular Arrhythmia	Long Term ECG	Normal Sinus Rhythm	Sudden Cardiac Death Holter	ST-T
Records amount	15	6	13	4	10	24	33

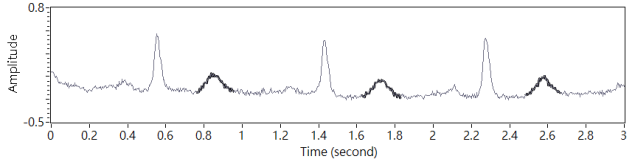
ESC: European Society of Cardiology

Database ECG will test

- original signal
- signal with 60 Hz power line
- signal with Gaussian white noise



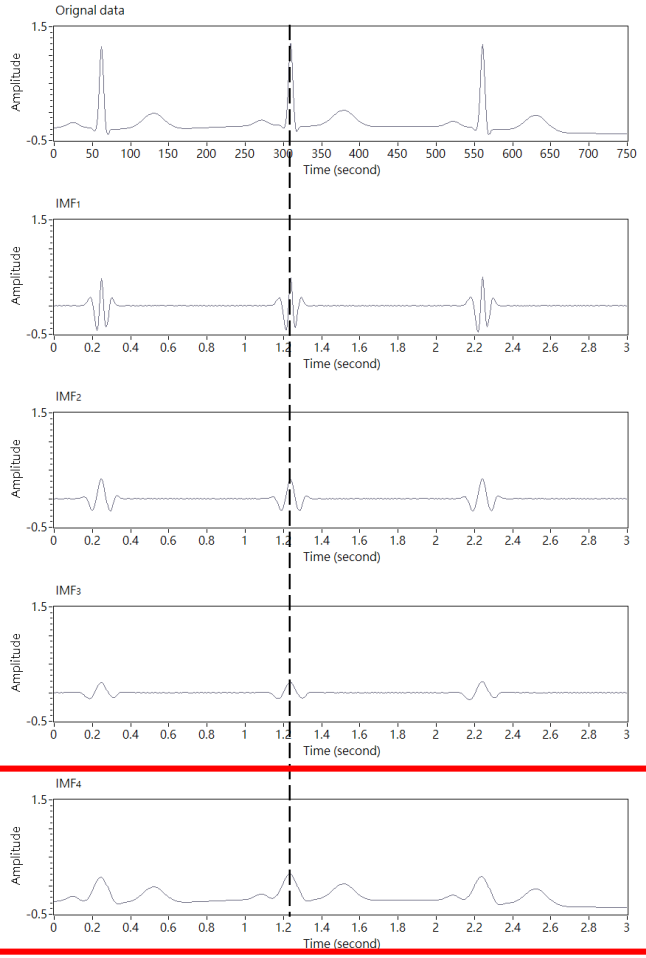
signal with 60 Hz power line



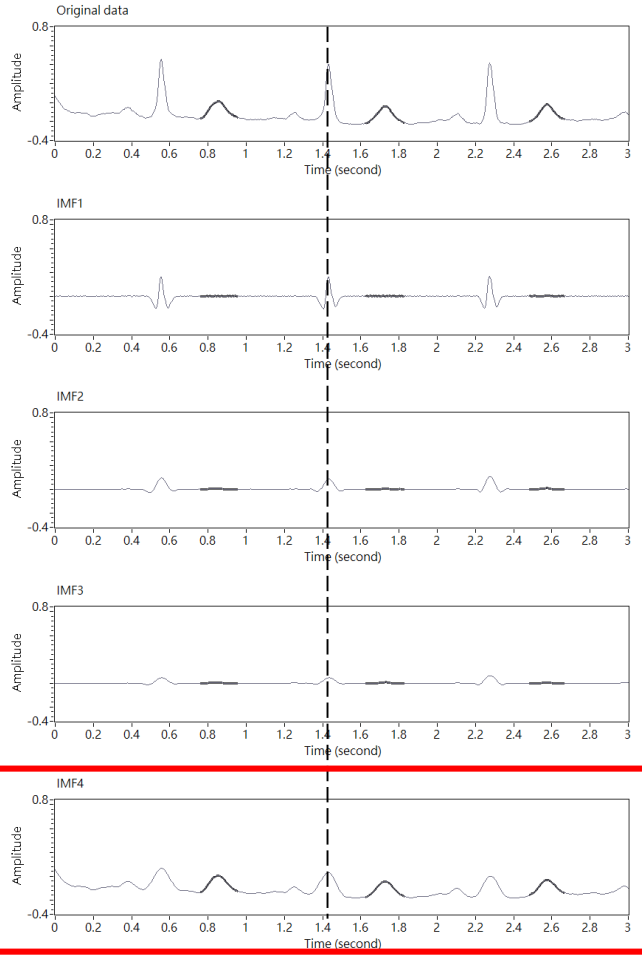
signal with Gaussian white noise

Result

➢ Simulated ECG



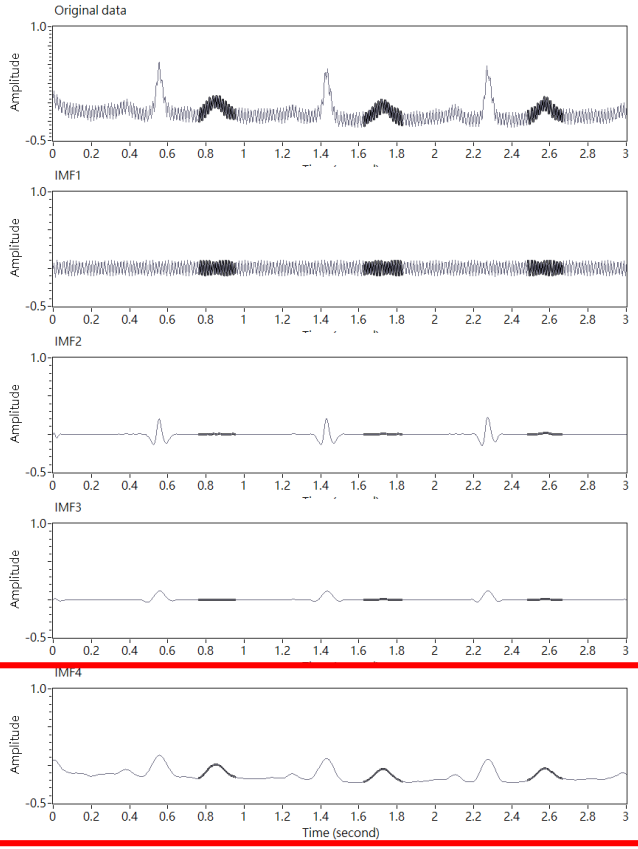
➢ PhysioNet QT database ECG



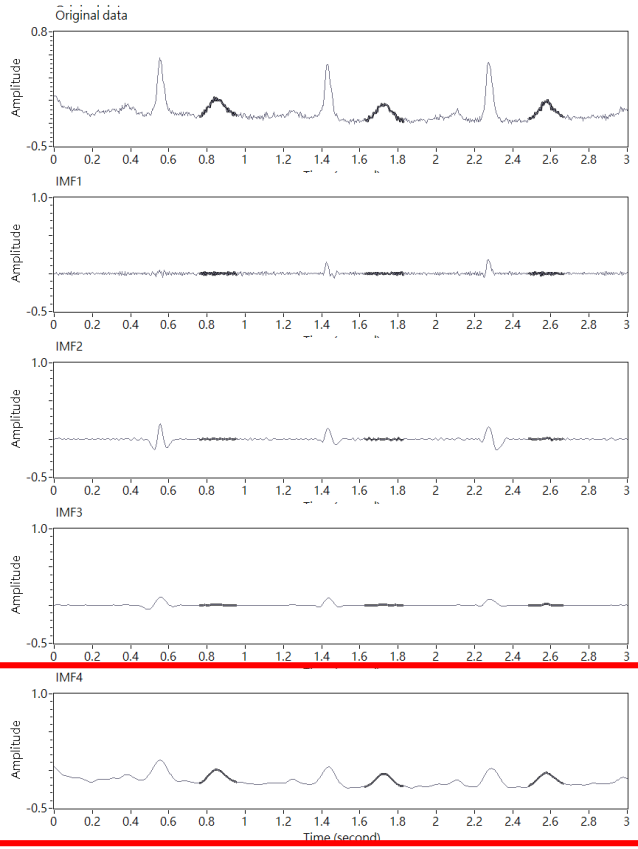
- ✓ **Main component with T-wave information was retained in the last IMF**
- ✓ **QRS-complexes' timing can be easily checked**

Result

- **ECG signal with 60 Hz power line noise**



- **ECG signal with Gaussian white noise**

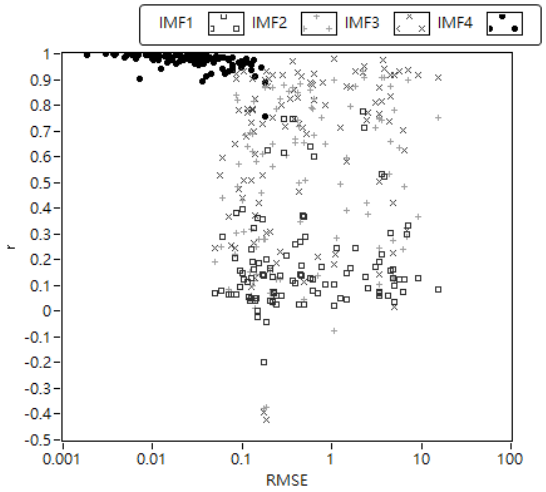


- ✓ **The noise is decomposed at IMF1**
- ✓ **Main component with T-wave information with almost no noise was retained in the last IMF**

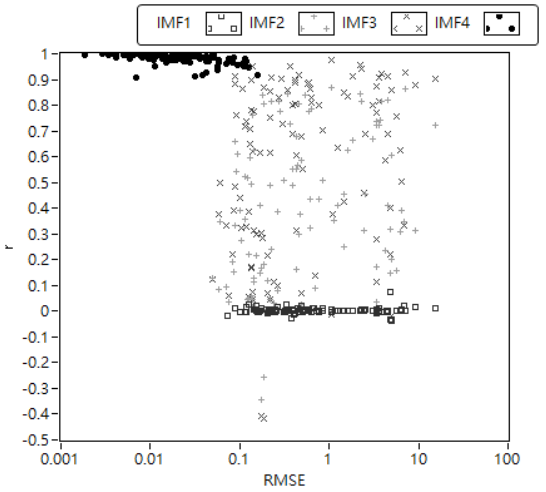
Discussion

105 records decomposed results

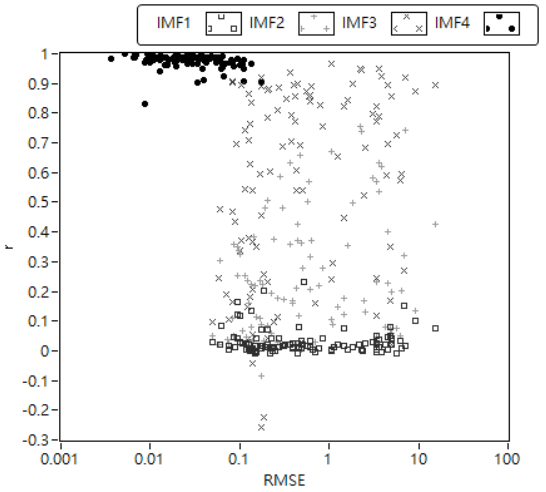
- Original ECG signal



- ECG signal with 60 Hz power line noise



- ECG signal with Gaussian white noise



✓ **IMF_4 has the highest correlation coefficient (r) and the lowest Root Mean Square Error (RMSE) with T wave!**

Discussion

- **The IMF_4's correlation coefficients are all over 0.95 and RMSE are all less than 0.04**

Judgment indicator	Signal treatments		
	Original signal	Add power line noise	Add Gaussian white noise
Correlation coefficient	0.97±0.03	0.98±0.02	0.98±0.02
Root mean square error	0.04±0.04	0.03±0.03	0.04±0.03

- **The results show that our method is useful for decomposing T waves**
- **The result demonstrates that our method has good performance in decomposing T-waves when the ECG signal has no negligible power line noise and Gaussian white noise.**

Conclusion

- **The results of ECG signal decomposition show that the proposed method extracts T wave well and is helpful for detecting QRS-complex timing.**
- **When decomposing ECG, modulated EEMD has less influence on power line noise and Gaussian white noise.**
- **This study might help for ECG feature extraction and detection.**
- **How to automatically mark ECG's features is the next important research.**

Acknowledgement

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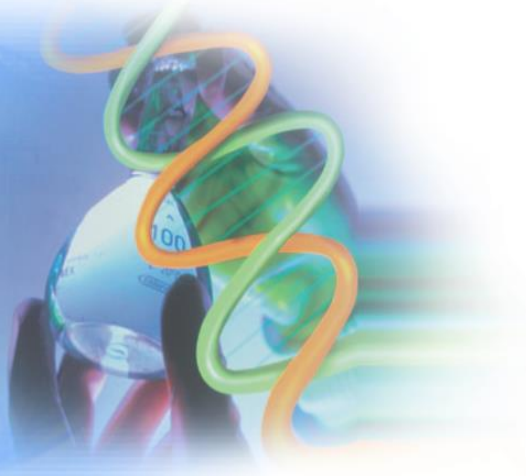
Thanks for your attention



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