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A comparison of methods for delineation of wave boundaries in 12 Lead ECG

Pauline Guyot^{1,3}, Pascal Voiriot⁴, Stéphane Papelier⁴, Levy Batista^{1,3}, Thierry Bastogne^{1,2,3}

¹CRAN, ²INRIA BIGS, ³CYBERnano, ⁴Banook CARDIABASE

Objective: In the diagnosis of cardiac diseases, the delineation of electrocardiogram is crucial in order to efficiently classify cardiac events. Delineation consists in **detecting the different peaks and boundaries** of the QRS-complex, P-wave and T-wave. Several techniques have been proposed to face this issue. The objective is to assess the detection performances of a recent approach (**non-negative matrix factorization**) that has never been applied to ECG delineation and to compare its results with three known methods: **morphological approach**, **discrete wavelet transform** and **difference operation method**.

Database

The data are composed of 516 original 12 Lead ECGs of 10 seconds coming from Banook database. All signals have been reviewed and annotated by cardiologists. The dataset combines normal cardiac activity but also a variety of cardiac arrhythmia.

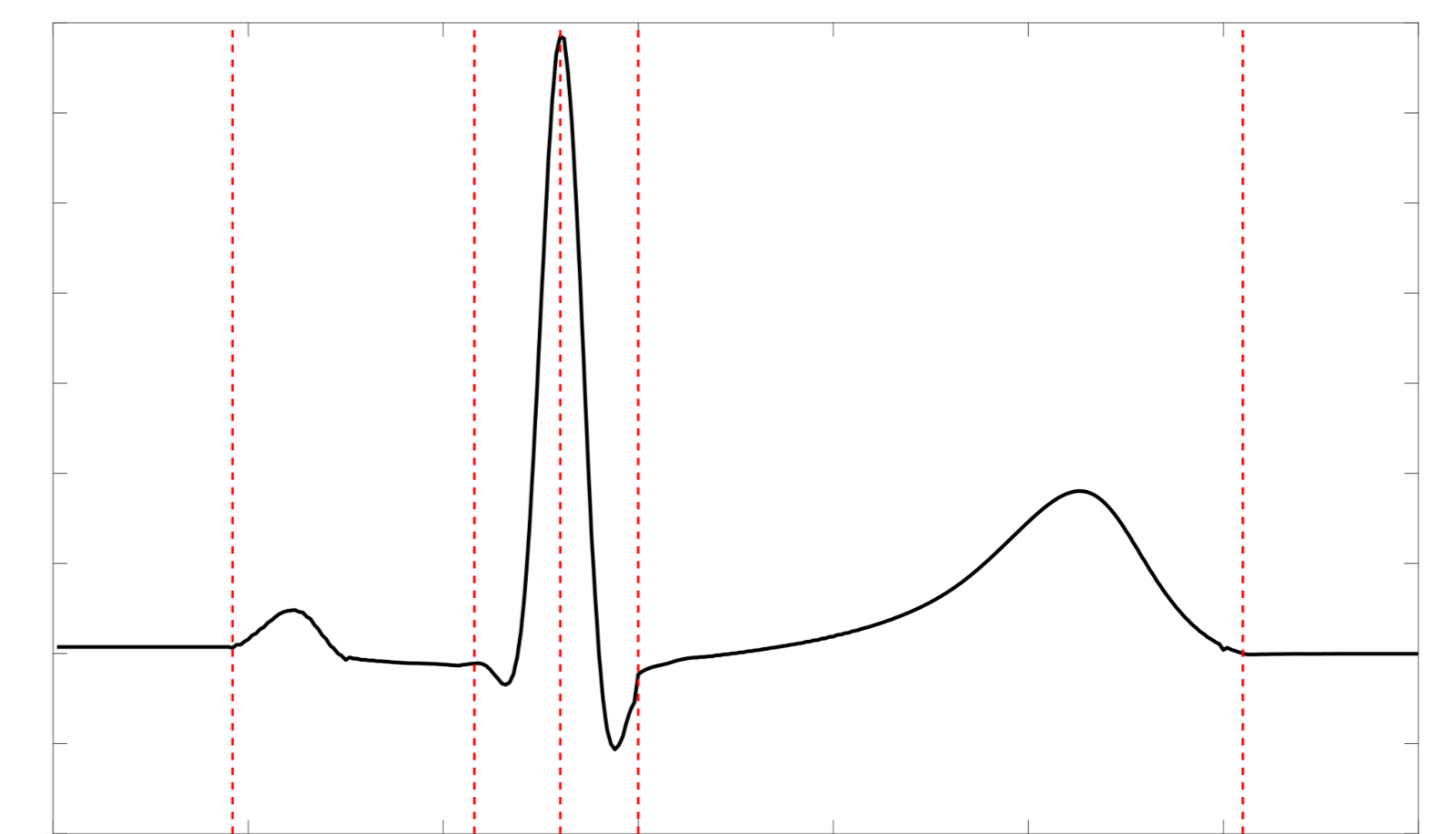


Image 1: Typical ECG signal with annotations (P-wave onset, QRS-complex onset and offset, R peak and T-wave offset)

Methods & results

The three known methods proceed the same way:

- Mathematical transformation (with morphological computing, DWT transform or difference operation),
- Dynamic or static thresholding for each waves
- Check with *a-priori* information

Non-negative matrix factorization is a method of blind source separation (**BSS**) which allow to recover source signals from signal mixture without any information on the model. The only constraint is the non-negativity of the signals. In our case, we use the **spectral information**.

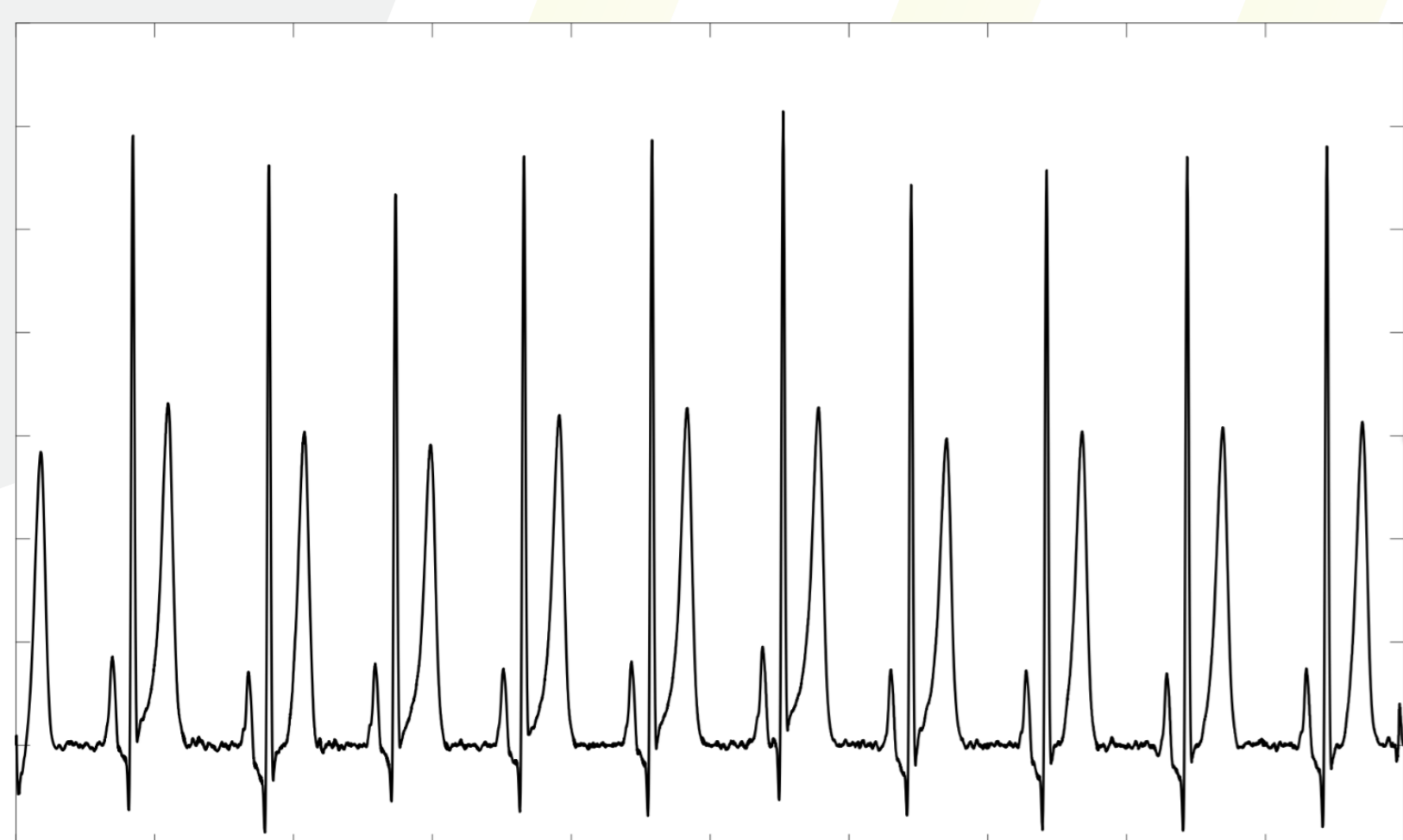


Image 2: ECG signal of 10 secondes (Lead I)

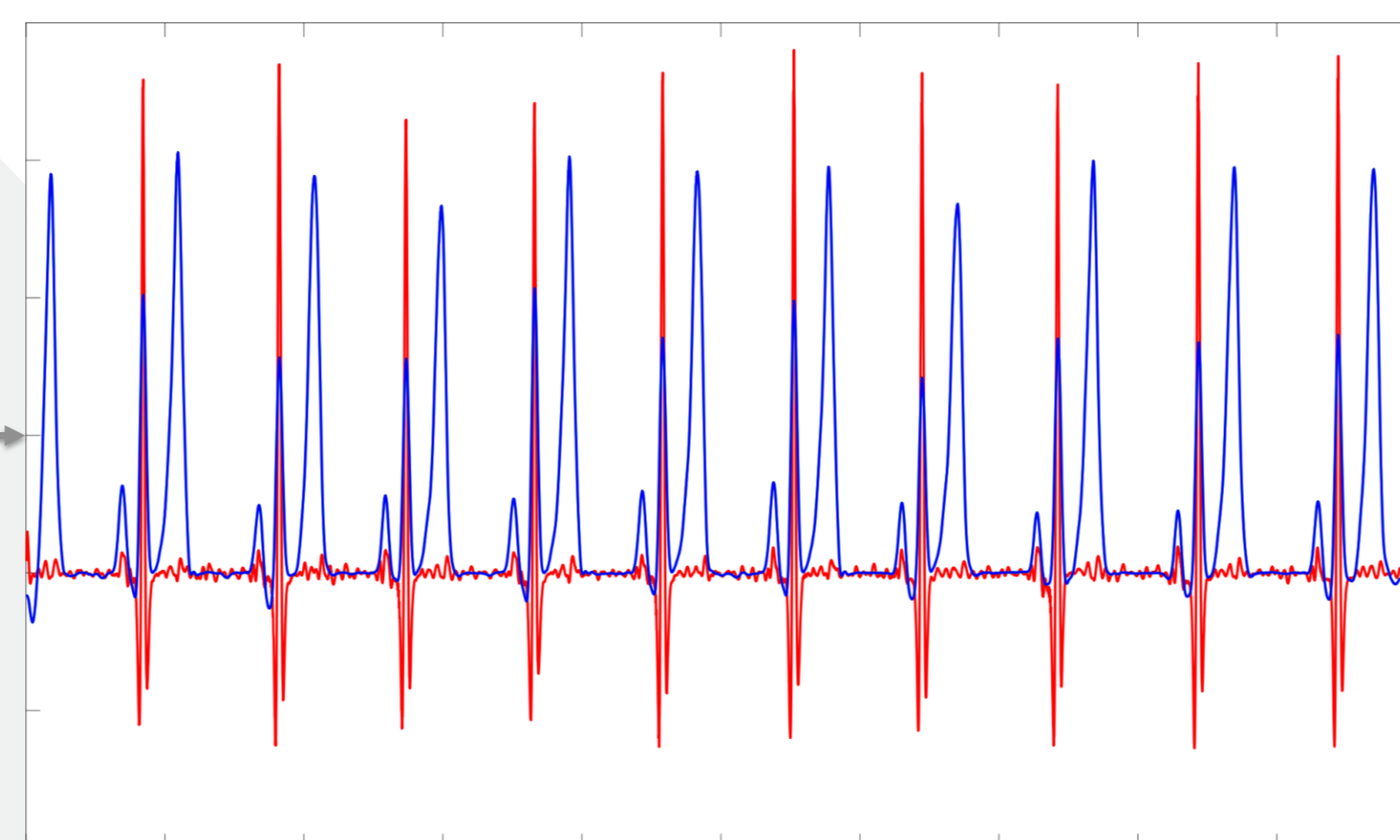


Image 3: NMF separation in two sources

First source concentrates **only R-peaks** whereas second source focuses on **P and T-waves** and a **part of QRS complexes**. As the spectral density of QRS complexes and other waves overlap, it is normal not to exactly separate QRS and non-QRS parts.

Methods	P-wave onset	T-wave offset	QRS onset	R peak	QRS offset	Time of execution	QT interval	QRS interval
Morphological approach	0,082 ± 6,178	-0,104 ± 11,092	-0,550 ± 4,856	0,416 ± 1,824	-0,078 ± 7,278	0,2677 (seconds)	0,446 ± 12,10	-0,472 ± 8,749
DWT approach	1,688 ± 7,556	0,674 ± 17,008	0,612 ± 4,260	0,568 ± 2,018	0,704 ± 6,886	0,1257 (seconds)	0,062 ± 17,53	-0,092 ± 8,097
Difference operation method	-	-	0,108 ± 4,665	0,636 ± 5,998	0,724 ± 7,060	0,3967 (seconds)	-	-0,616 ± 8,462
NMF	0,522 ± 36,12	0,298 ± 29,06	0,825 ± 11,916	0,016 ± 1,247	-1,084 ± 21,20	2,5518 (seconds)	-0,527 ± 31,40	1,909 ± 24,31

Tab. 1: Error between cardiologists annotations and algorithms' results (in milliseconds) and time of execution (in Matlab R2017a)

Main issues with NMF :

- **Nonuniqueness property** of NMF (reconstructed signals can vary significantly)
- **Time consuming**
- **Blind source separator** (can separate R peaks from non-QRS parts but also noise from meaningful signal, necessity of a supervisor)

Conclusion

Delineation of **R-peaks** is the **easiest target to be accomplished**, whereas the delineation of **non-QRS parts** (P-wave and T-wave fiducial points) is the **most challenging issue for all methods**. Improved techniques of NMF have to be investigated but first results show the feasibility of this method.