Blind Separation of Fetal ECG from Single Mixture using SVD and ICA

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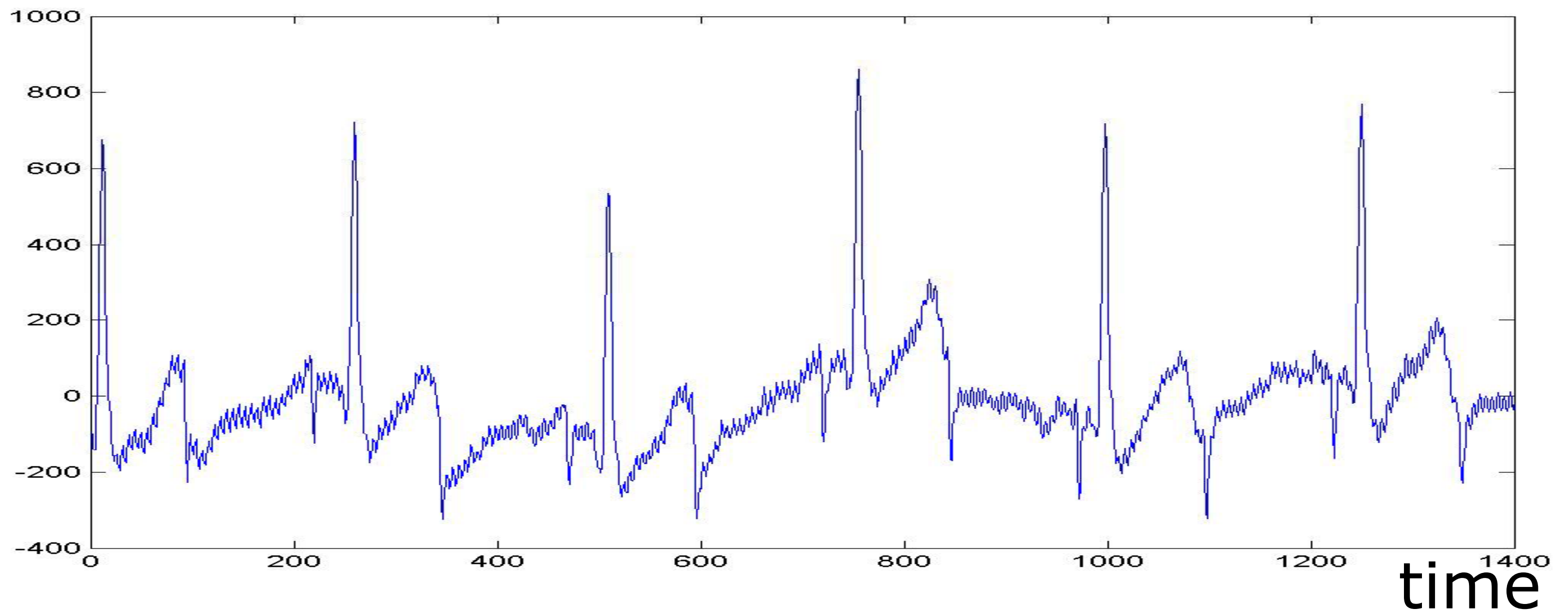
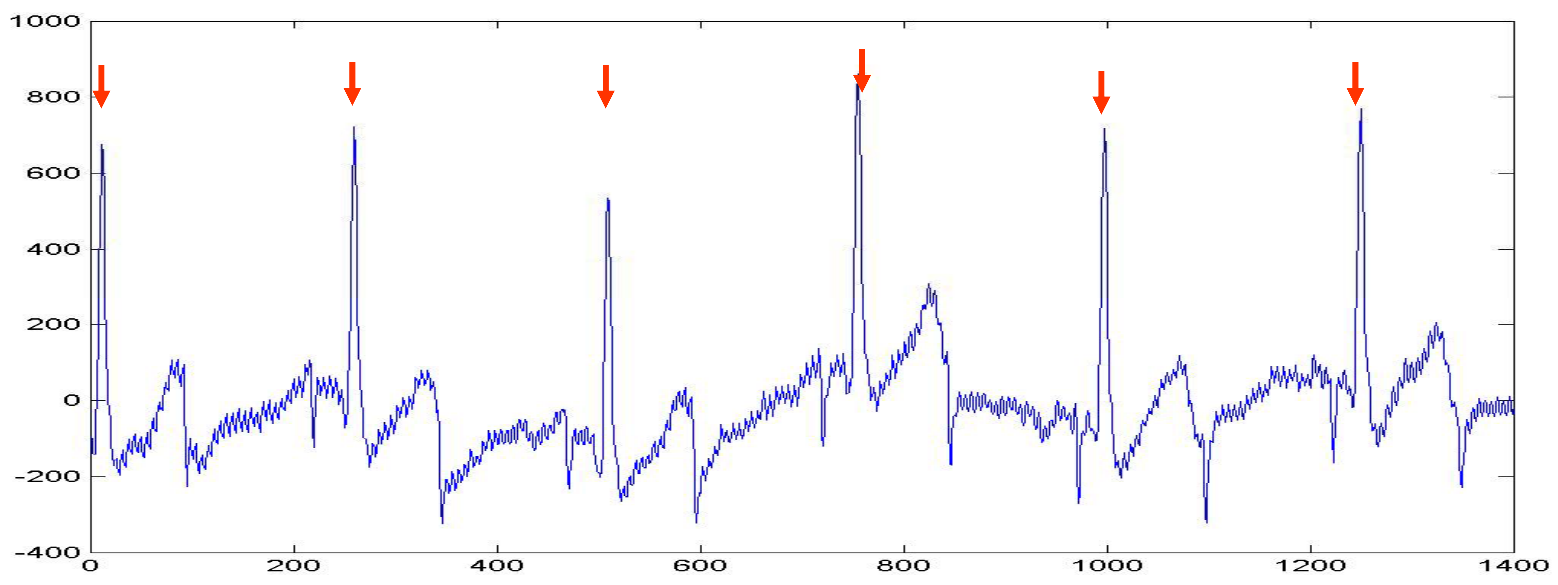
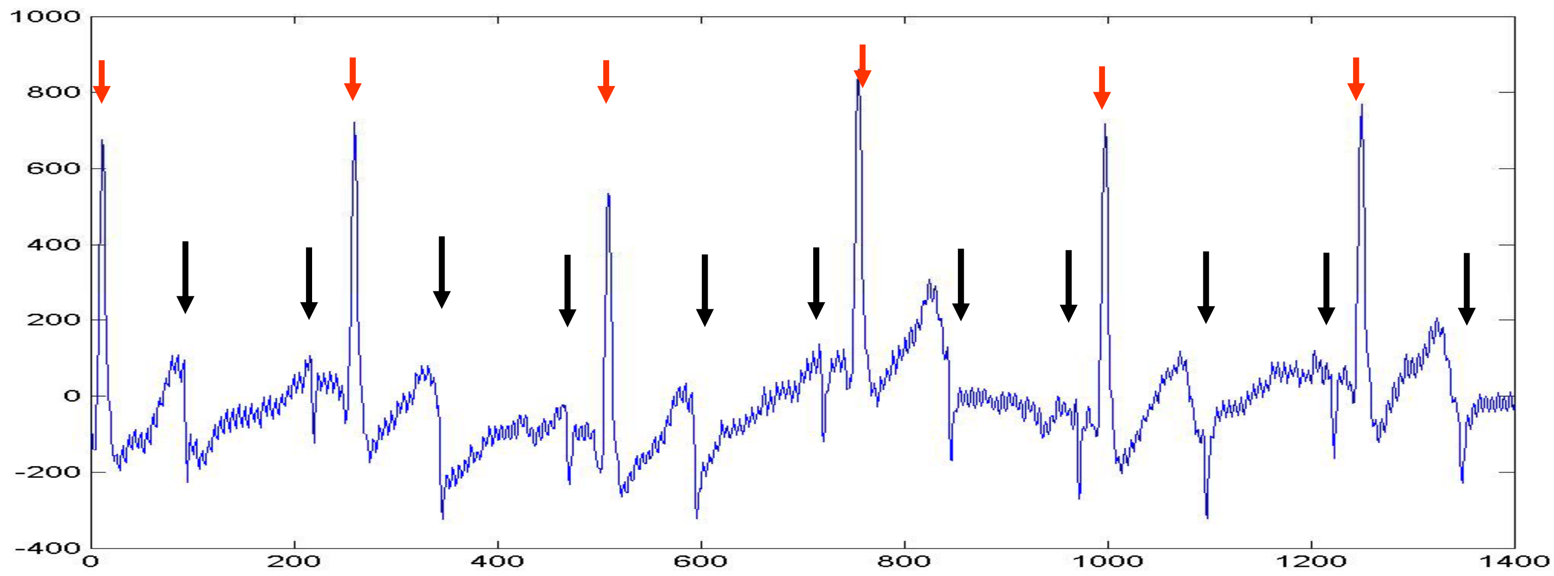


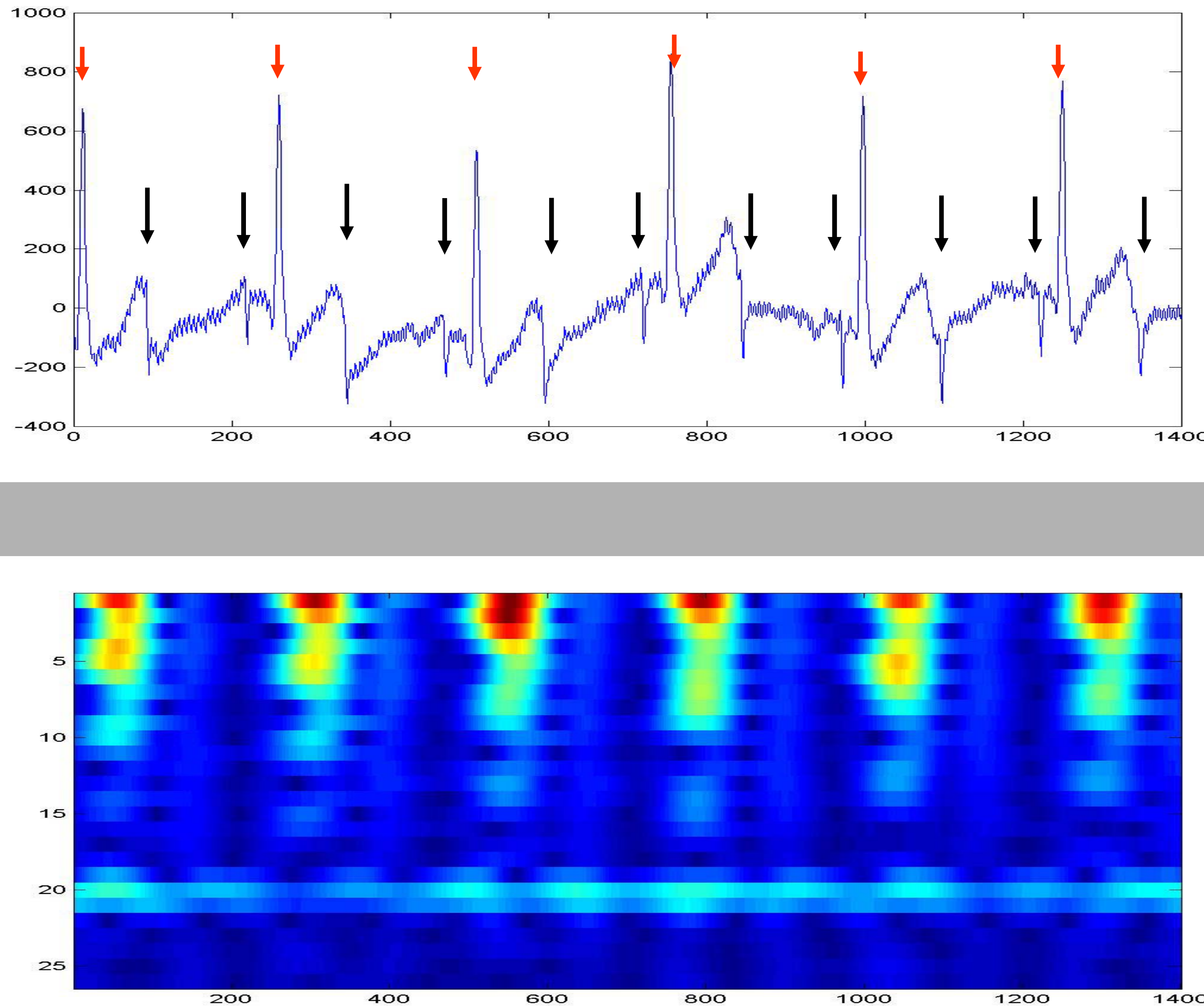
Mixed ECG's for a period of roughly 4.6 seconds



Maternal heartbeat (R)



Fetal heartbeat


1000
800
600
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200
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1200
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5
10
15
20
25
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600
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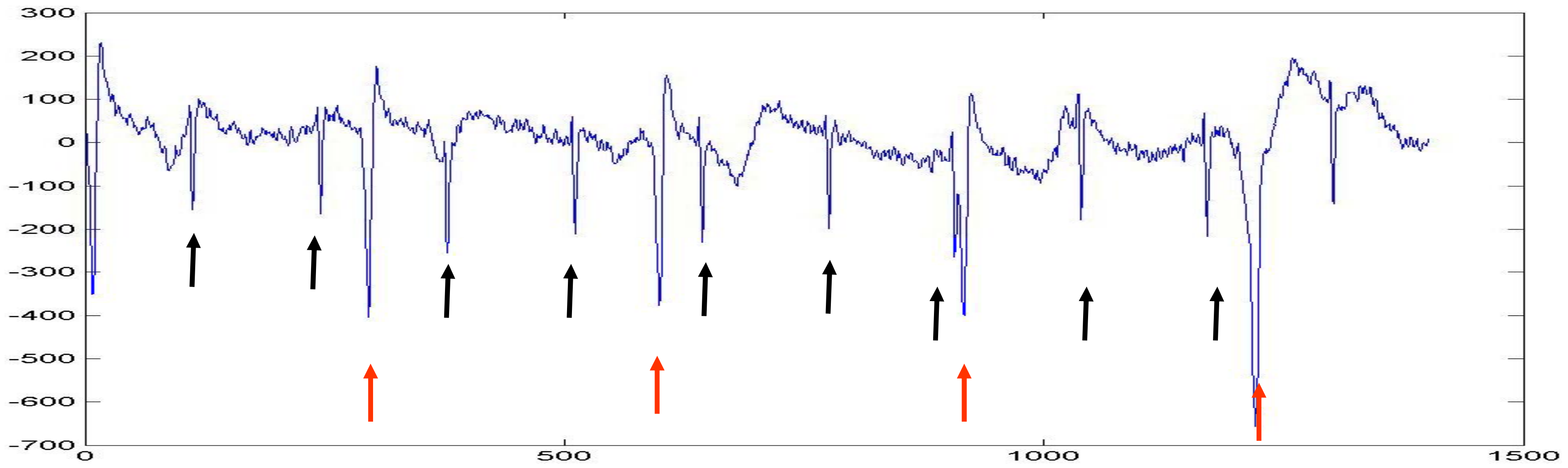
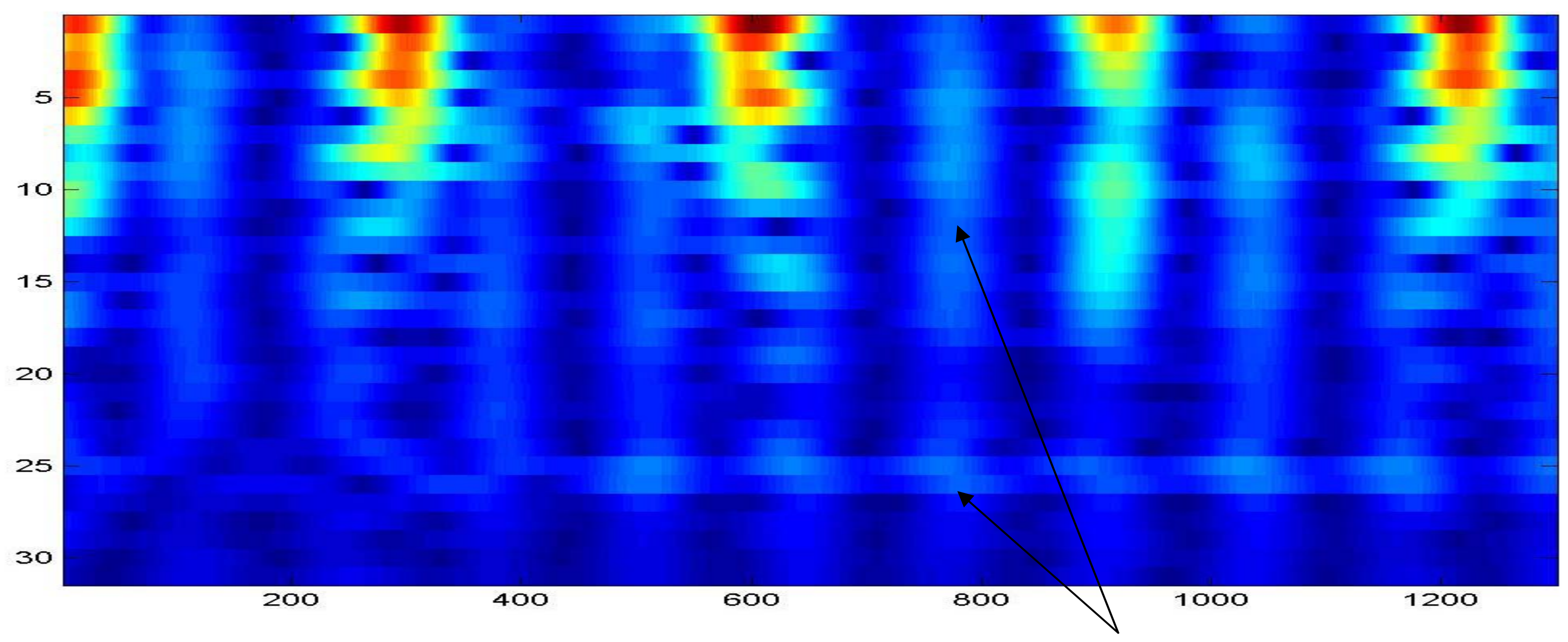
1000
1200
1400



300
200
100
0
-100
-200
-300
-400
-500
-600
-700
0
500
1000
1500



5
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15
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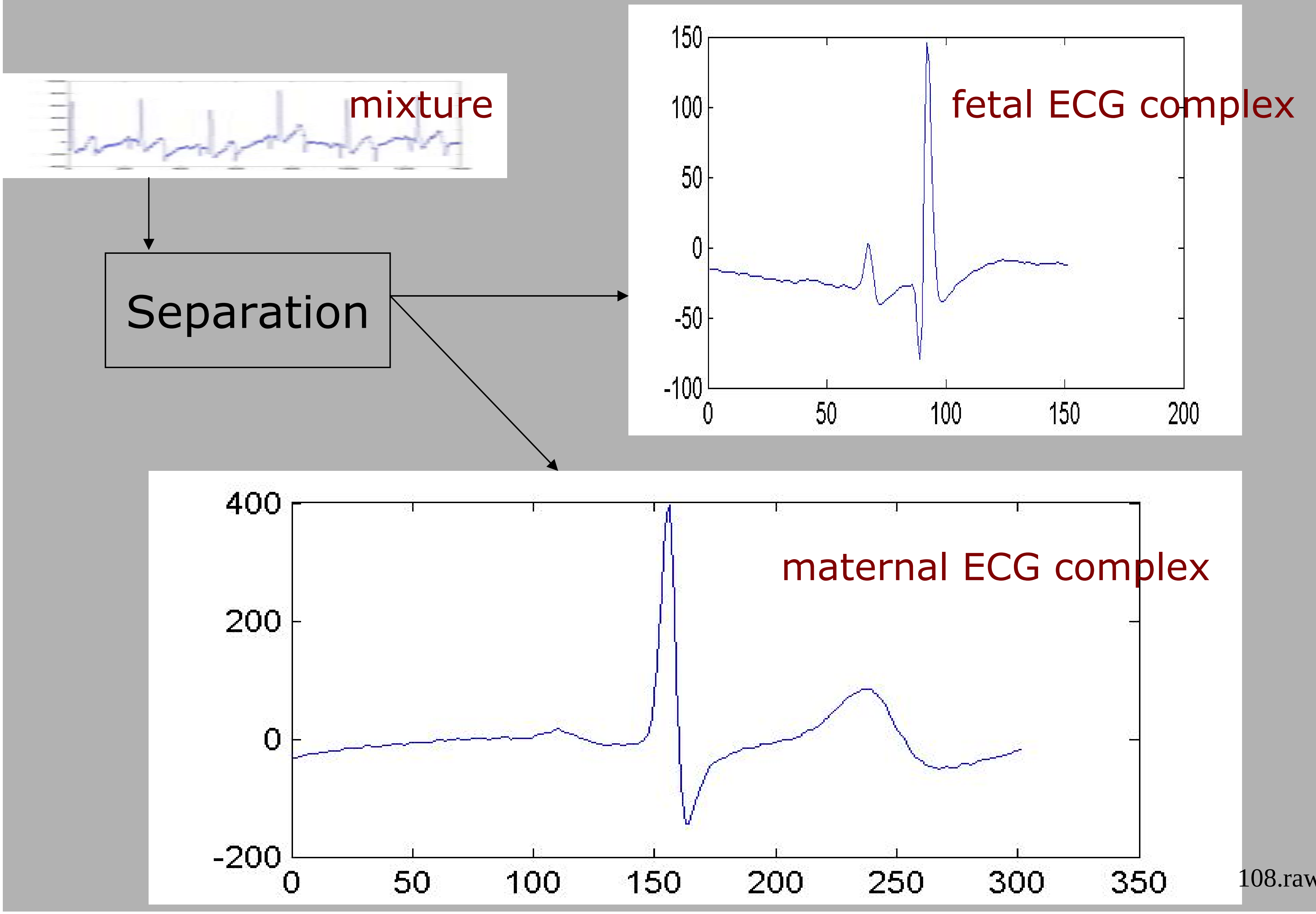
200
400
600
800
1000
1200

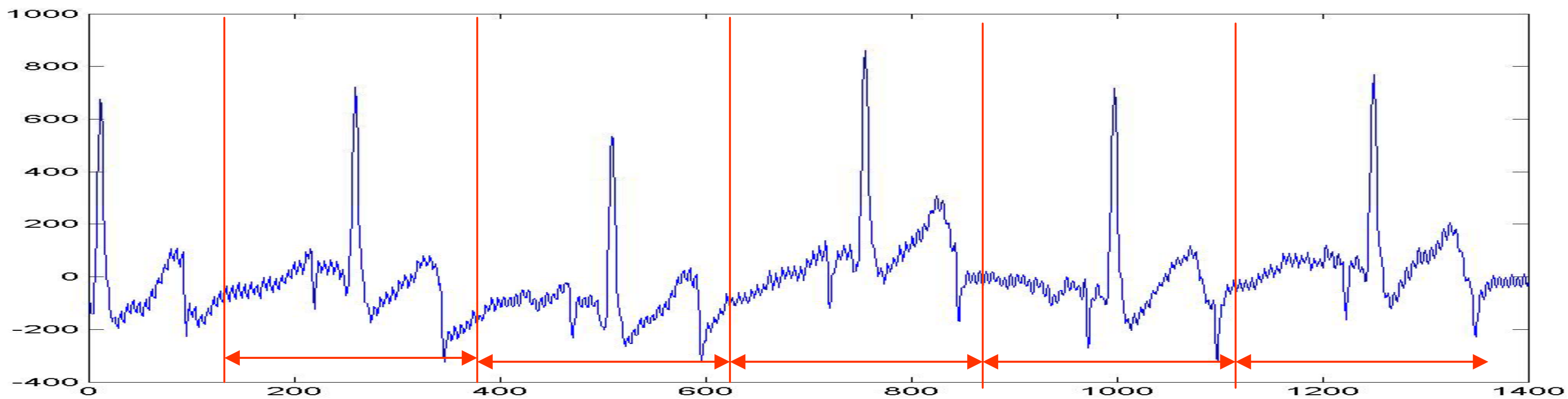
Goal: separation from a *single* mixture



One Approach

1. Find the occurrences of maternal heartbeat by identifying the peak
2. Find the maternal ECG complex by “averaging”
3. Subtract the maternal ECG complex from the mixture.

4. Repeat the above for fetal ECG.

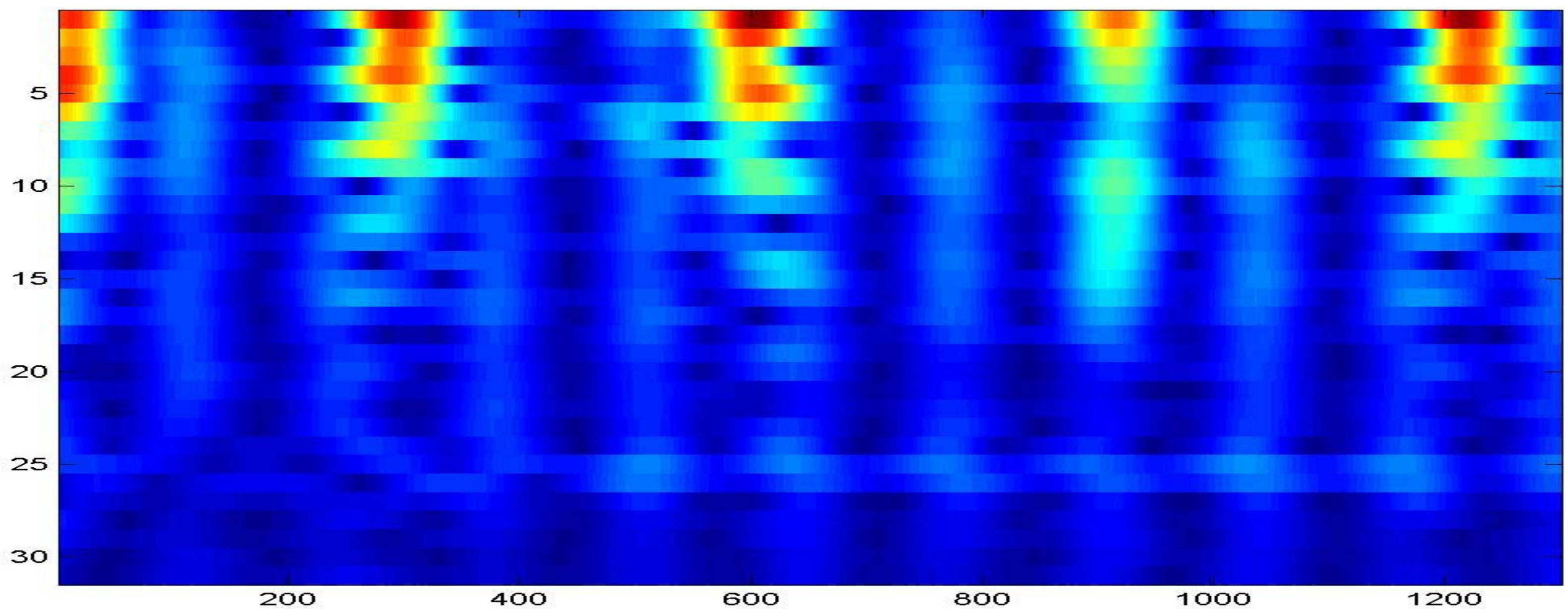


Disadvantage: require significant fine-tuning in step 1 and 3.

Main Idea

- Identify the heart beat in the spectrogram.
- Observation: with the right window size used in the spectrogram, a ECG complex in the spectrogram can be viewed as a separable function.

$$f(s,t) = f(s)\, f(t)$$



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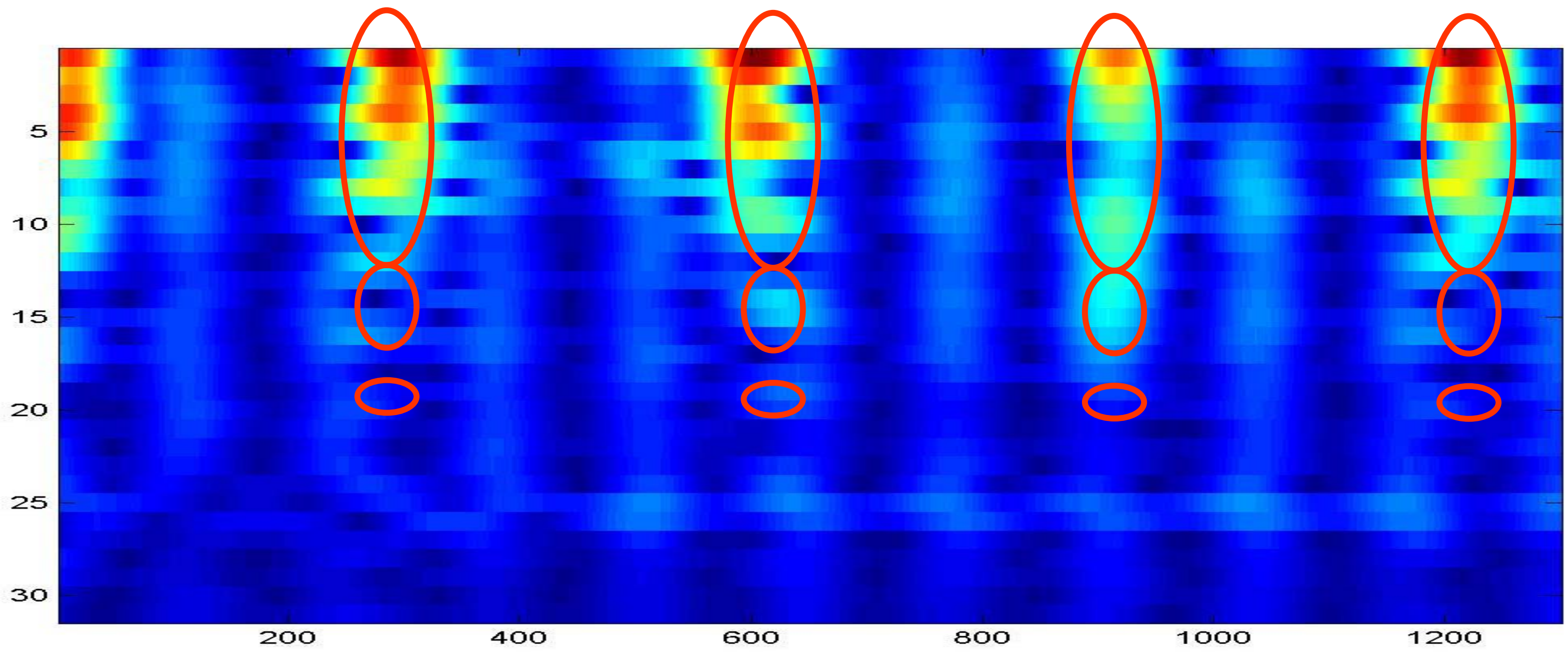

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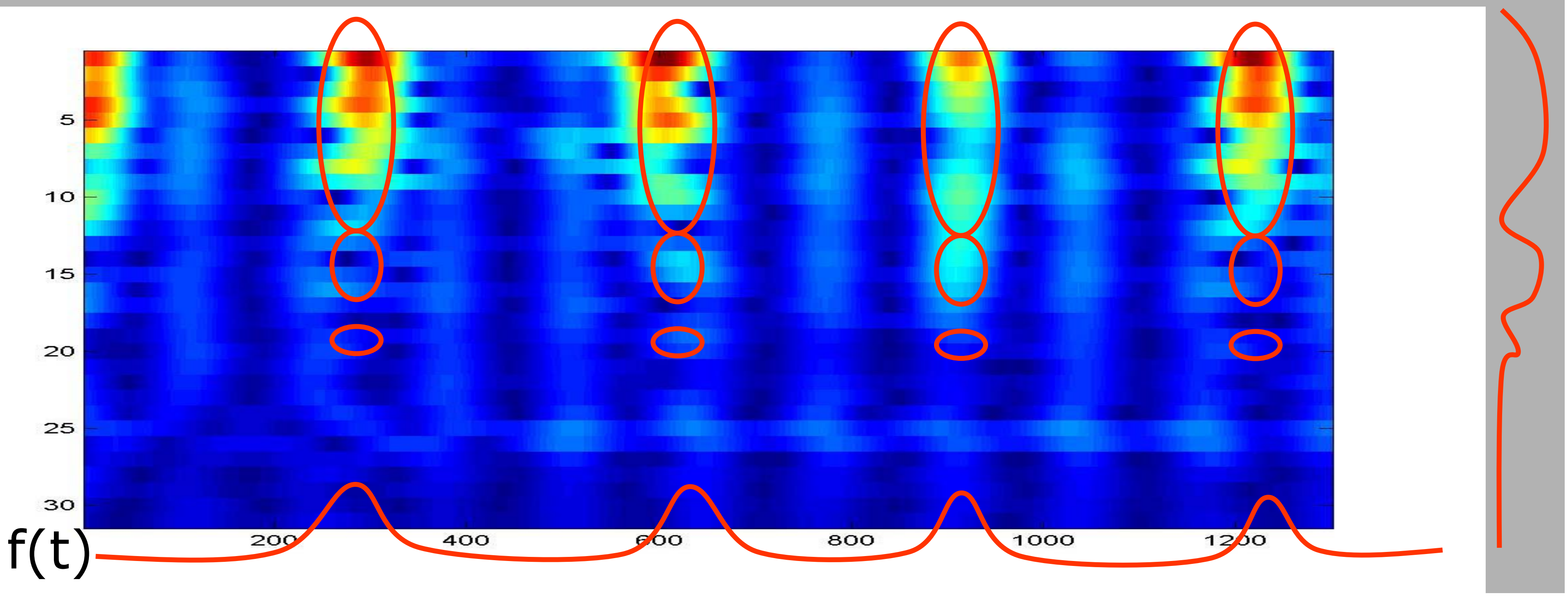

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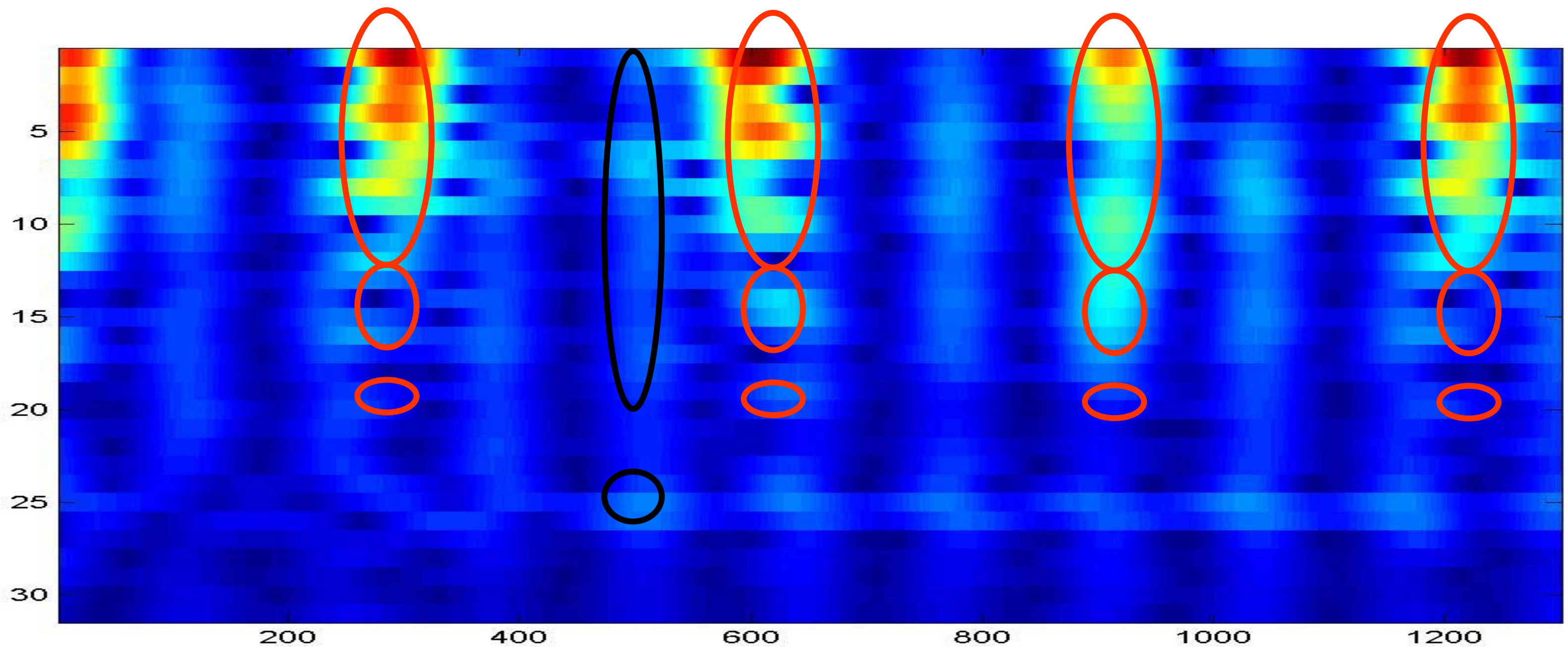

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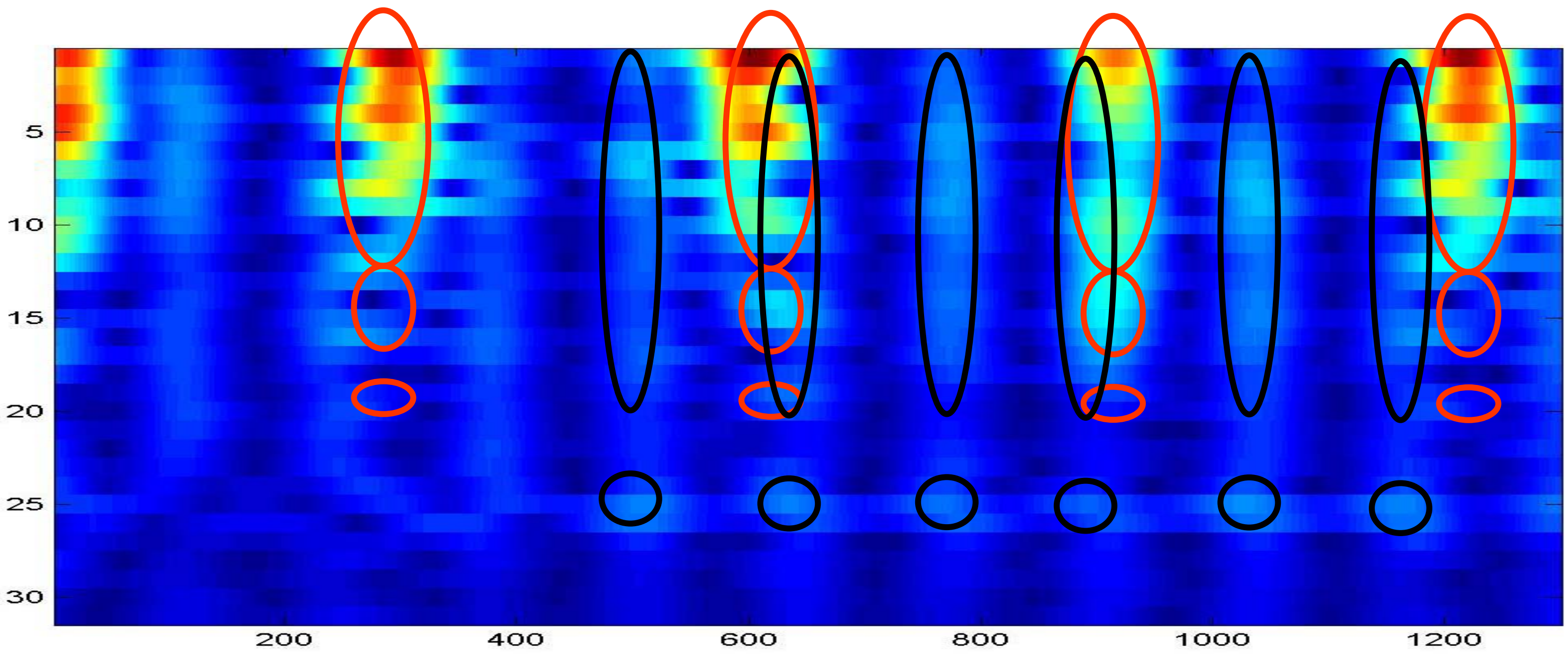
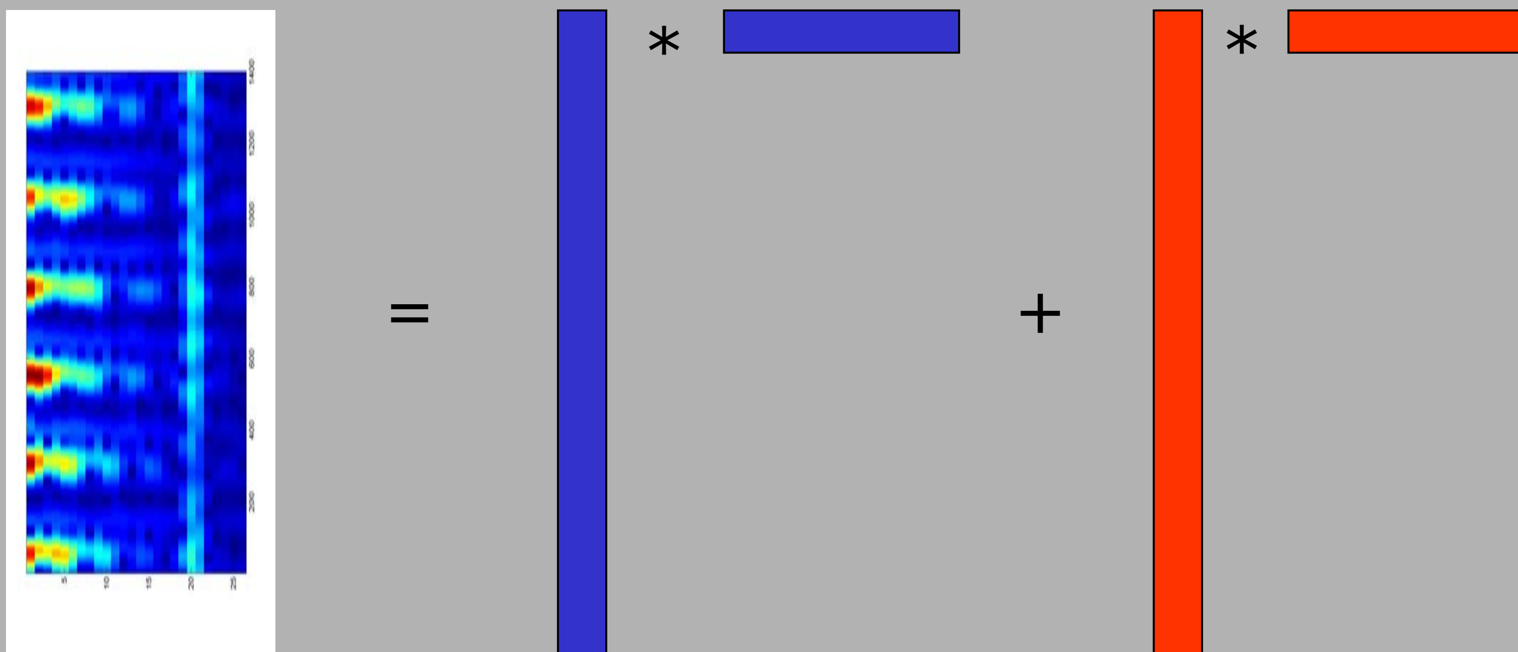


we want to find the "best" U_m, V_m , U_f and V_f s.t.

$$S = U_m V_m + U_f V_f$$



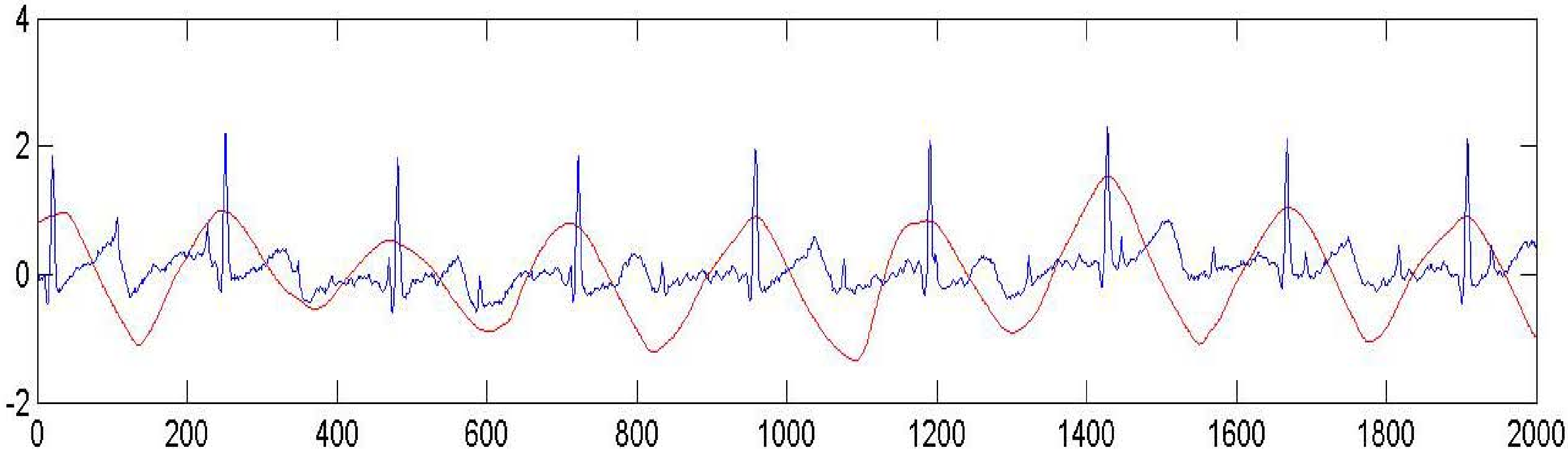
Suppose we want to find the solutions that minimized the noise in the sense that $|| N ||^2$ is minimized,

$$S = U_m V_m + U_f V_f + N$$

then, we can employ the well-known SVD.
However, experimental studies show that it gives unsatisfactory results.

We borrow idea of ICA
(Independent Component Analysis).
In the proposed algorithm, we attempt to find the solutions that are “statistically independent” and non-Gaussian like.

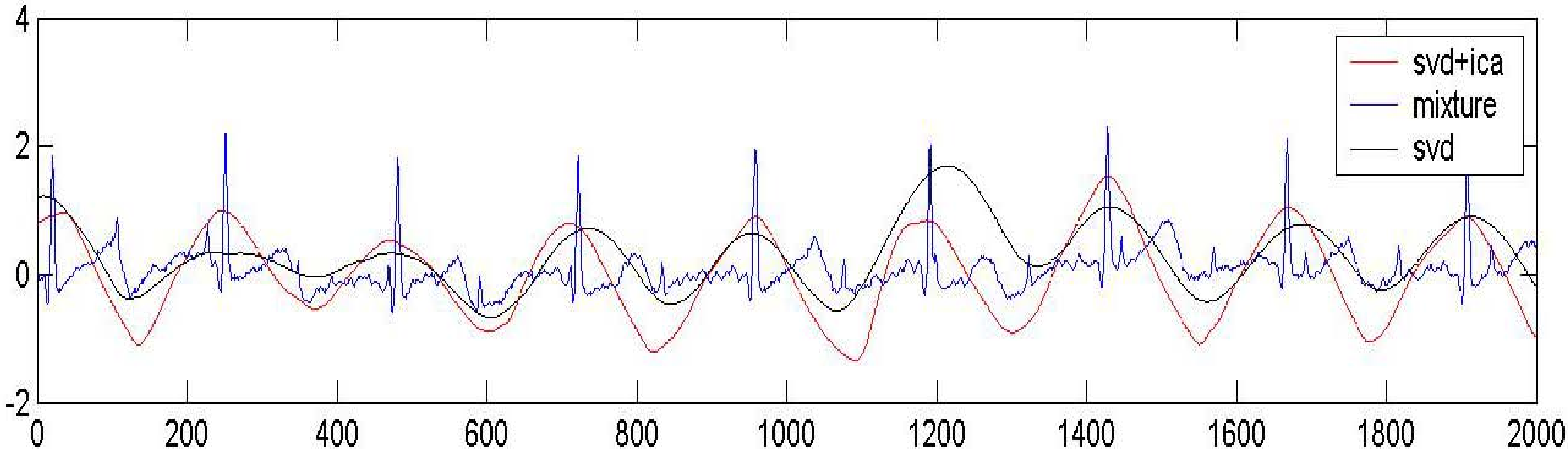
Experiments



Maternal heartbeat trend U_m using ica+svd

292.raw

Experiments



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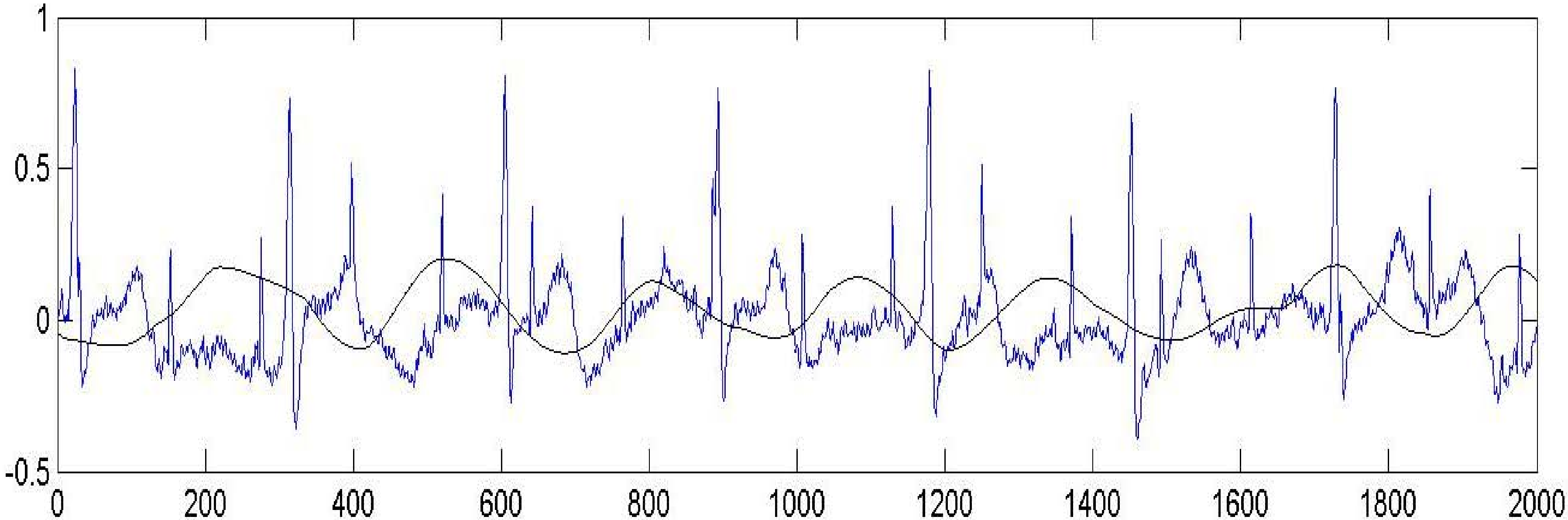
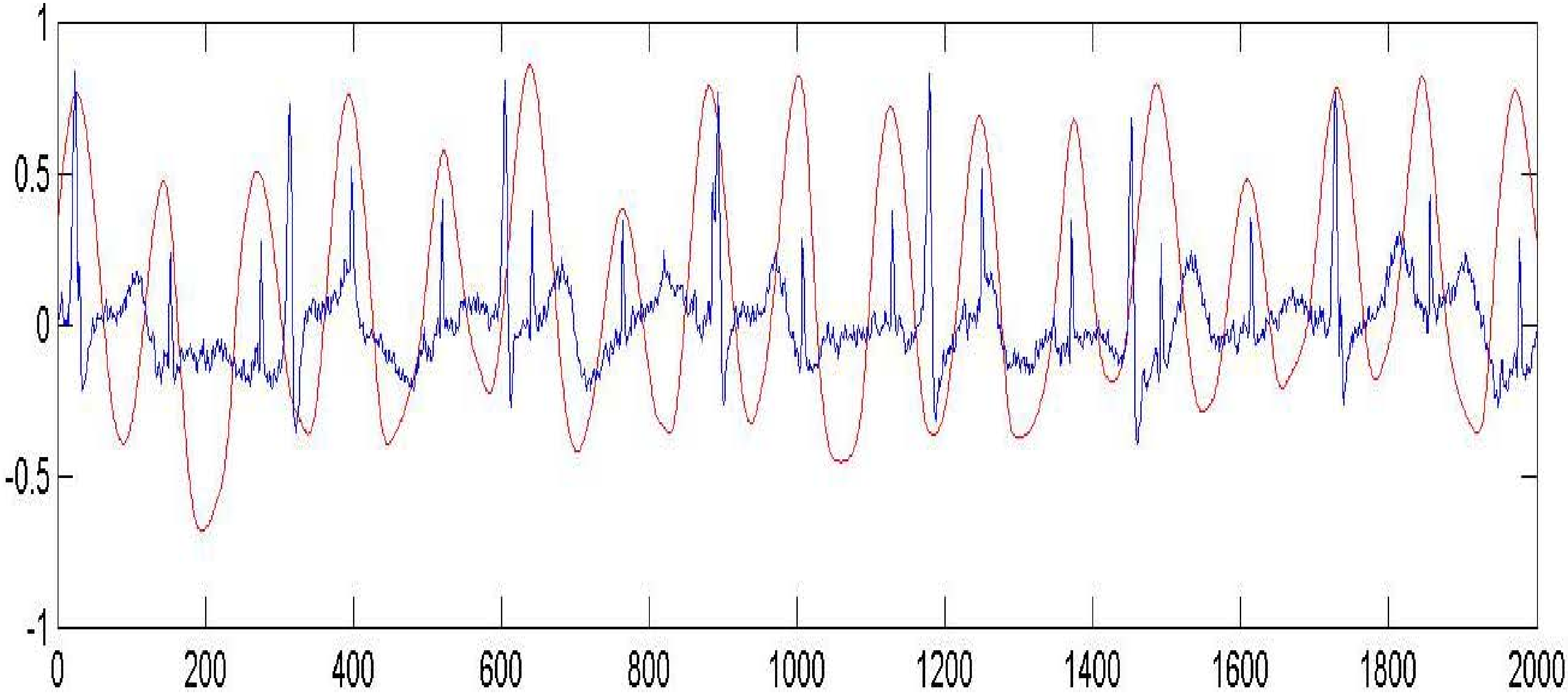


Fetal heartbeat trend U_v using SVD

108.raw

Experiments



Fetal heartbeat trend U_v using svd+ica

Independent Components Analysis

$$x_1(t) = a_{11}\, s_1(t) + a_{12}\, s_2(t)$$
$$x_2(t) = a_{21}\, s_1(t) + a_{22}\, s_2(t)$$

unknowns > equations,   under constrained.

We want to find the s_1 and s_2 which has maximum independence and minimum nongaussianity.

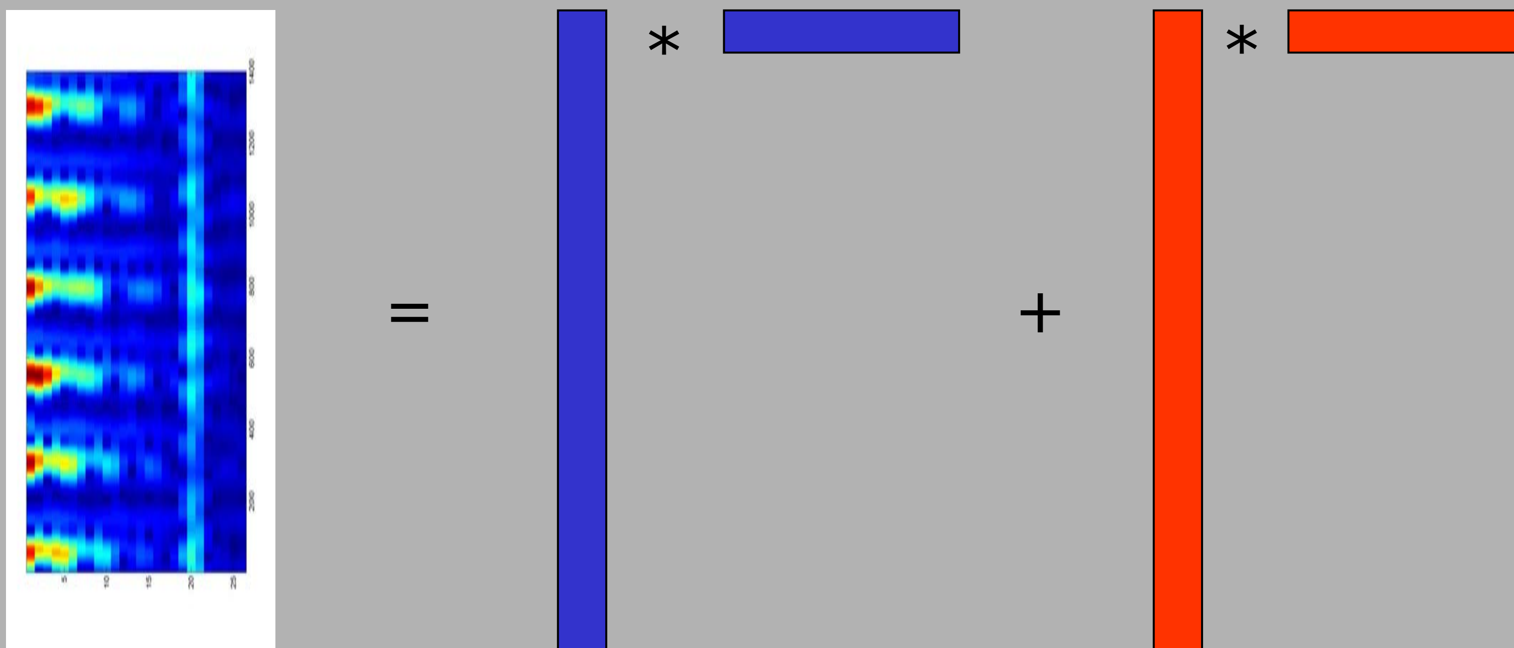
$$\sum s_1(t)\, s_2(t) = \sum s_1(t) \sum s_2(t)$$

Negentropy

In our experiment, we use FastICA

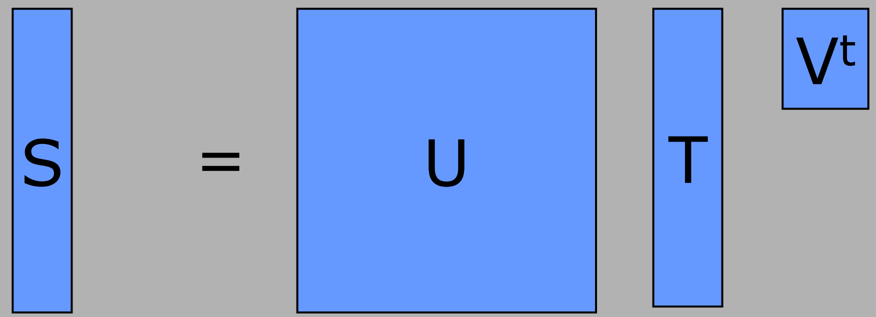
we want to find the "independent" U_m, V_m , U_f and V_f s.t.

$$S = U_m V_m + U_f V_f$$



Proposed method

1. Compute Spectrogram S
2. Perform SVD on S, $S = U\,T\,V^t$



3. Apply ICA on the k most significant spectral components, i.e. on V_1, V_2, V_3, …, V_k.
4. Update the U using the mixture obtained in step 3.
5. Apply ICA on the k most significant spectral of the updated U.
6. Choose two ``best'' components in U and call them u_m and u_f.

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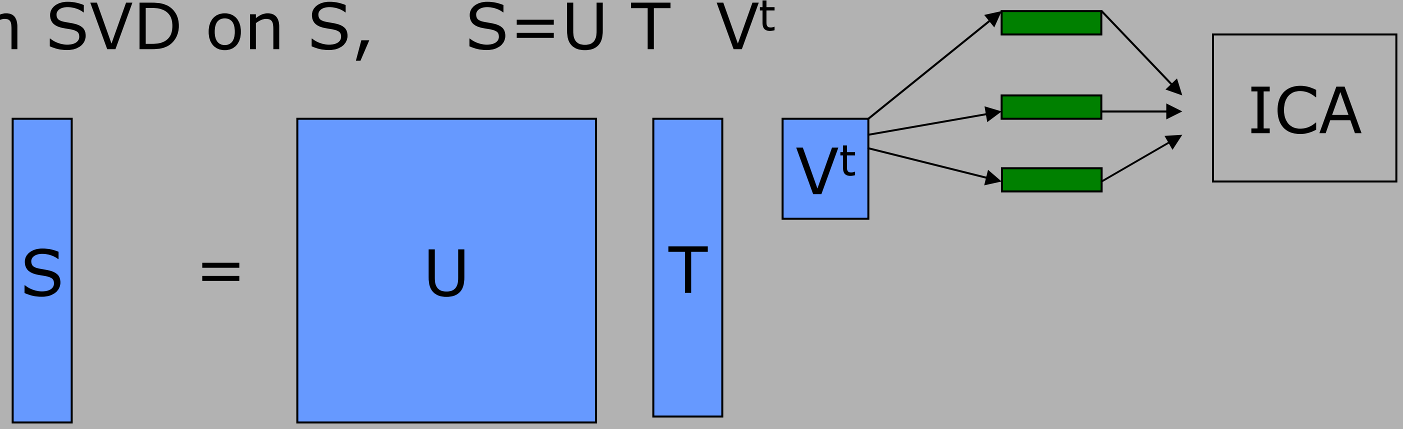

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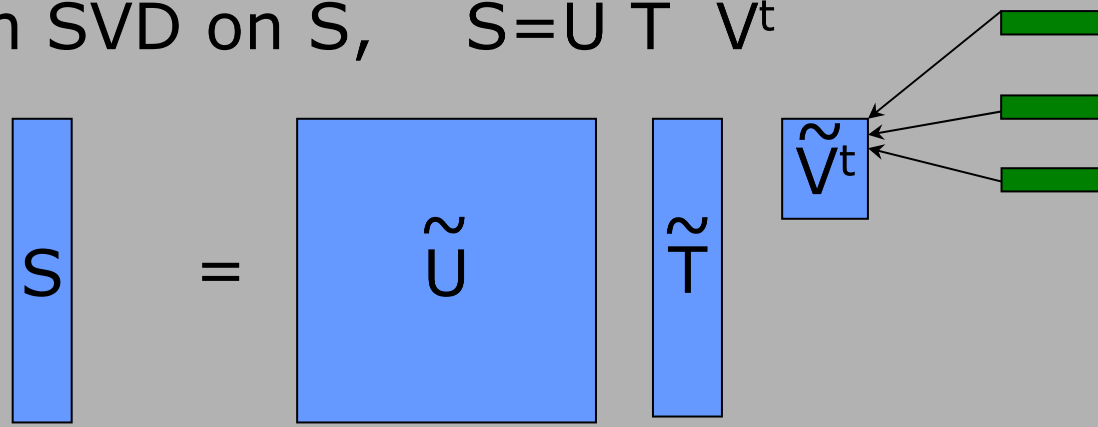

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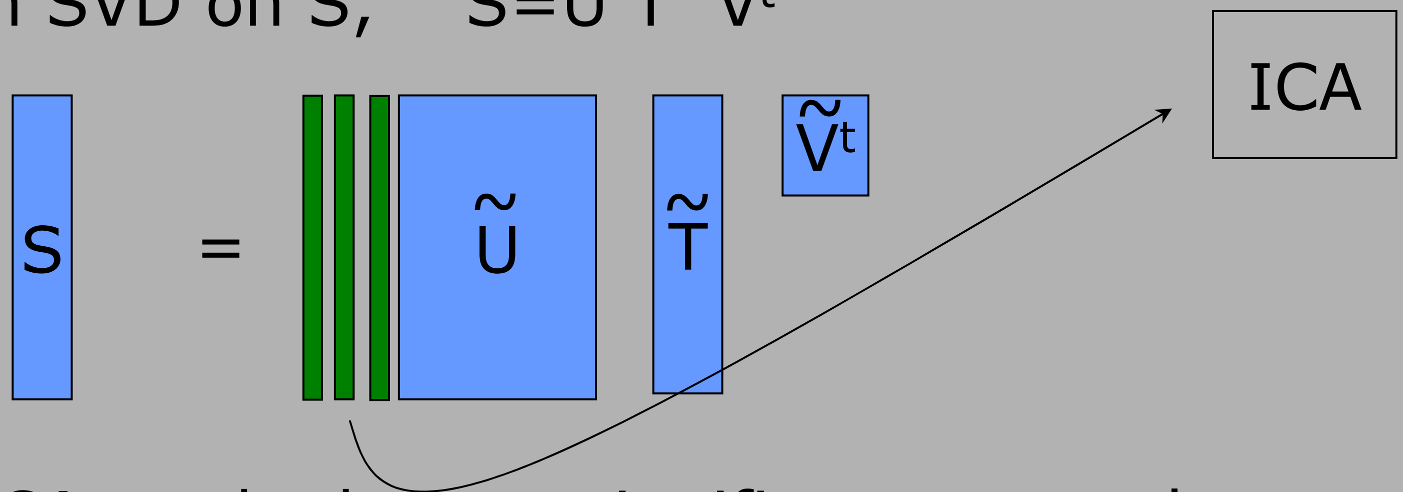

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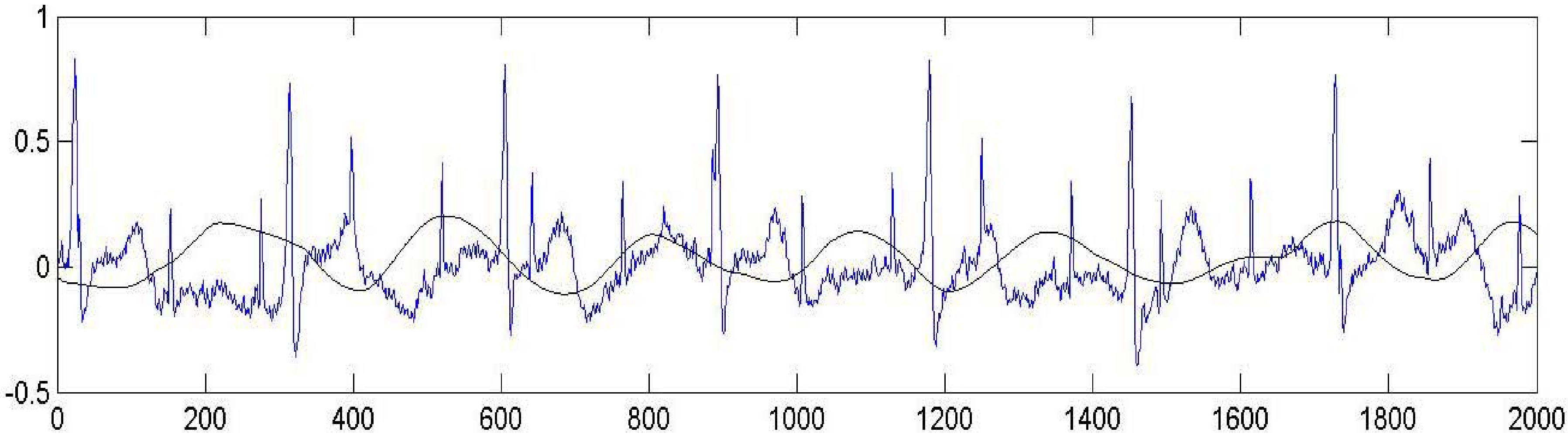
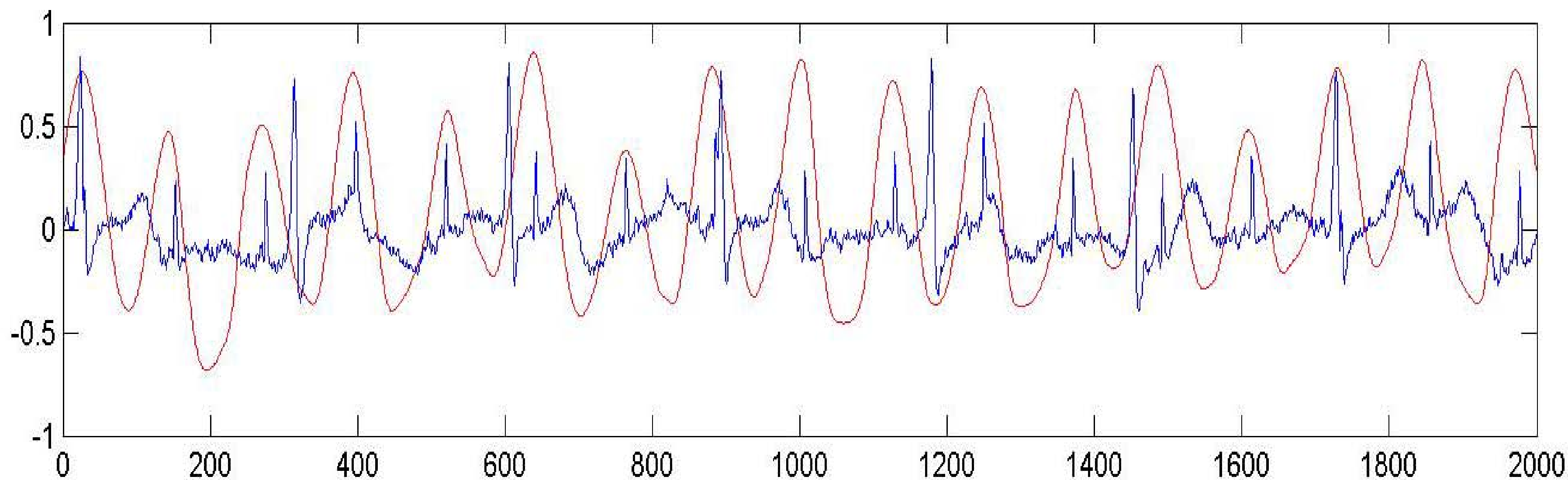


Components obtained after SVD



Components obtained after SVD + ICA

Remarks & Future works

1. The proposed method does not find the intended u_f and u_m as stated in the formulation. It is an approximation.

2. Extend the method to other applications.

3. More analysis.

Acknowledgement

We would like to thank
Prof Ho Ting Fei, Department of Physiology, National University of Singapore, for providing the data-sets.