Catching Physiological Noise: Comparison of DRIFTER in Image and *k*-Space

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Introduction

- We aim to improve the signal-to-noise ratio (SNR) of fMRI through accurate treatment of non-white noises.
- The non-white noise is mainly induced by heartbeat, respiration, and variation in blood flow [1].
- Such structural noise is usually removed by retrospective methods [2, 3] using only the reconstructed magnitude images.
- We show how the DRIFTER [3] method can be extended to work with both *k*-space and complex image space data.
- The results show that it is beneficial to remove the noise components already prior to reconstructing the magnitude images.

DRIFTER

- DRIFTER [3] is a model-based method for retrospective estimation and removal of physiological noise.
- The method uses Bayesian optimal filtering methods, and it has shown excellent performance in comparison to other methods.
- DRIFTER combines information from fast-sampled physiological reference signals with the data to separate the noise.
- Decomposing the fMRI data into additive components:
  (1) Oscillatory structured noises
  (2) Slow drift and the BOLD signal
  (3) Unstructured residuals
- The idea is visualized in Figure 1.

Material

- A 27-run set of resting state fMRI data and anatomical images for one volunteer obtained with a 3 T scanner (Siemens Skyra; 32-channel coil array).
- EPI sequence parameters: TR: 77 ms; TE: 21 ms; FA: 60°; FOV: 224 mm; matrix size: 64×64; and voxel size: $3.5\times3.5\times6$ mm.
- EPI trajectory parameters: ramp times: 140 μs, flat-top time: 220 μs, and ADC readout time: 409.6 μs.
- Cardiac and respiration reference signals time-locked to the fMRI data using peripheral pulse measure and a respiratory belt.
- We used two harmonic resonators in the DRIFTER algorithm.

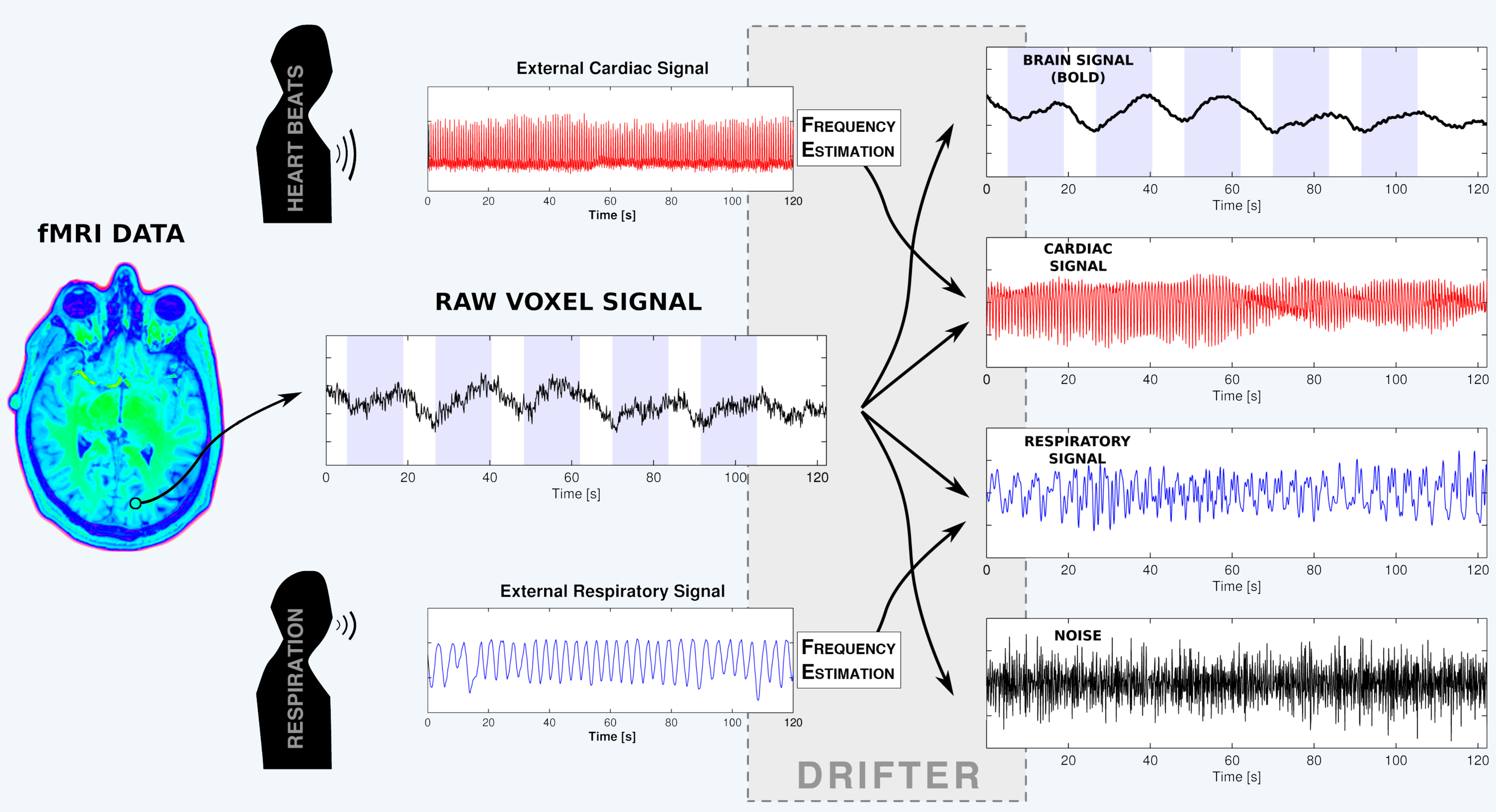

Figure 1: The DRIFTER method for separation of physiological noise in fMRI data. Each voxel time series is dealt with independently.

The DRIFTER toolbox for Matlab/SPM is available online: `http://becs.aalto.fi/en/research/bayes/drifter/`

Methods

- We apply the DRIFTER method to:
  (1) Magnitude images (standard sum-of-squares reconstruction)
  (2) Complex-valued reconstructed coil images
  (3) Raw *k*-space data before reconstruction
- In the complex-valued data, the real and imaginary components were dealt with independently.
- We used Kaiser–Bessel regridding [4, 5] in the reconstruction.
- The final maps for the complex and *k*-space data were weighted by the coil images when summing over the channels (as in sum-of-squares reconstruction).
- Amplitude maps are compared against the anatomical image.
- This analysis is done for each set of data/slice independently.

Results

- In Figure 2, we show cardiac noise amplitude maps for a set of slices and separated at different stages of the reconstruction.
- The comparison of the complex and magnitude image space data DRIFTER deals with each voxel spatially independently, whereas in the *k*-space data, DRIFTER is independent over the *k*-space.
- The results show differences in the spatial localization of the noise.

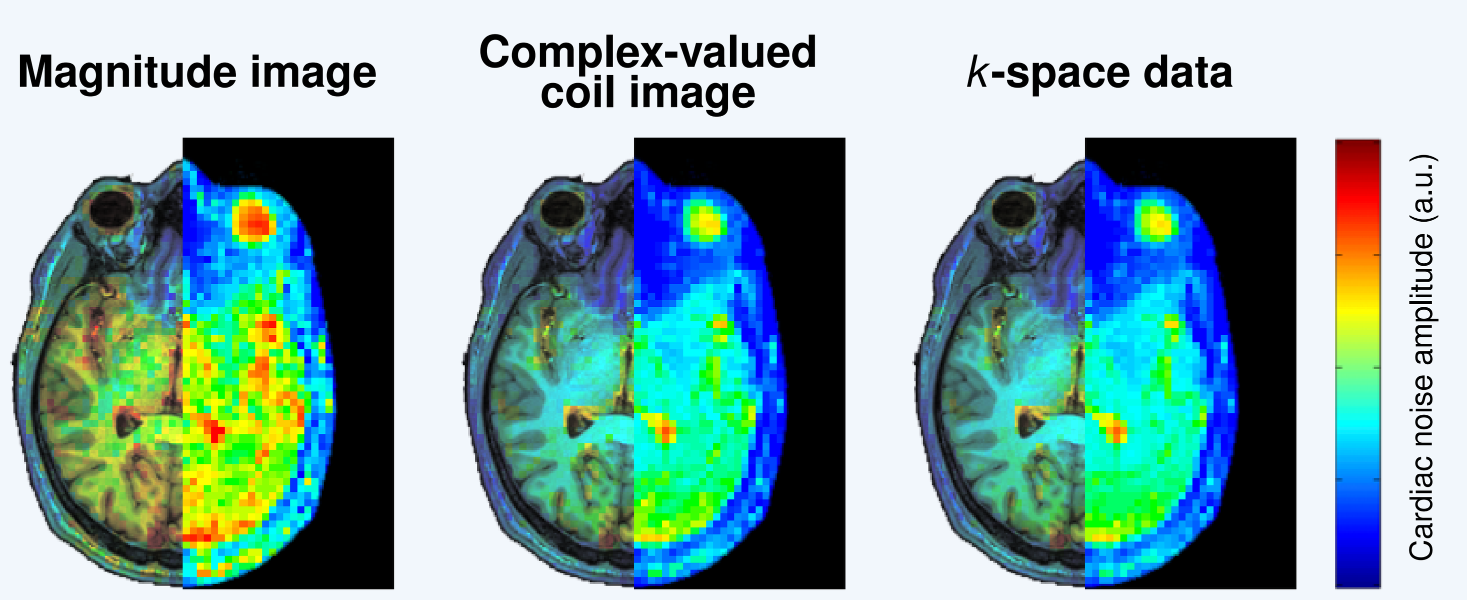

Figure 2: Cardiac noise amplitude maps (slice 14) reconstructed from the magnitude image data and compared to maps from complex coil image data, and *k*-space data. The noise magnitudes are logarithmic and may vary between the methods.

Discussion

- The overall map structures agree with earlier results [6].
- The results should in theory be similar, as the components in DRIFTER are purely additive and the inverse Fourier transform reconstruction is a linear operation.
- However, there are clear differences in the noise reconstruction between the magnitude images, and the complex image and *k*-space data.
- The latter ones are almost identical, the slight differences stem from the non-uniform sampling of the *k*-space.
- The results imply that the noise influence is clearly more localized in the complex and *k*-space maps, especially near the big arterial veins.
- Estimation of the structured physiological noise should be done before the noise effects get aliased into the image data.

Conclusion

- We have presented how the physiological noise removal method DRIFTER can be applied to complex-valued fMRI image data and raw *k*-space data.
- The findings motivate further development of tools for catching physiological noise.
- The DRIFTER toolbox for SPM8 and Matlab is available for download online.

References

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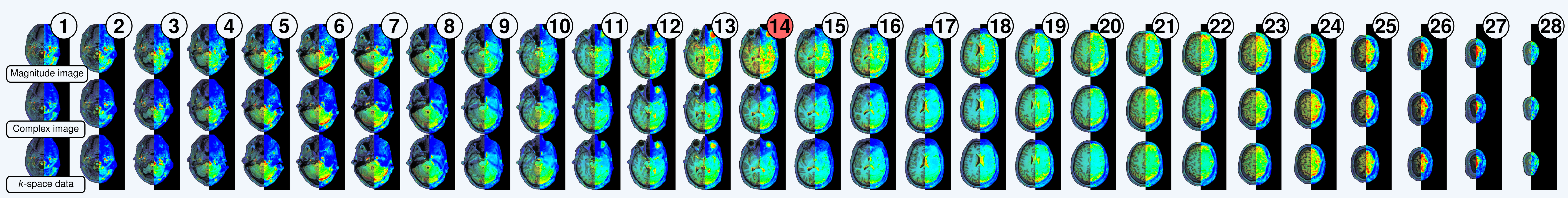

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