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Dictionary learning via regression: vascular MRI application

Fabien Boux^{1,2}, Florence Forbes¹, Julyan Arbel¹ and Emmanuel Barbier²

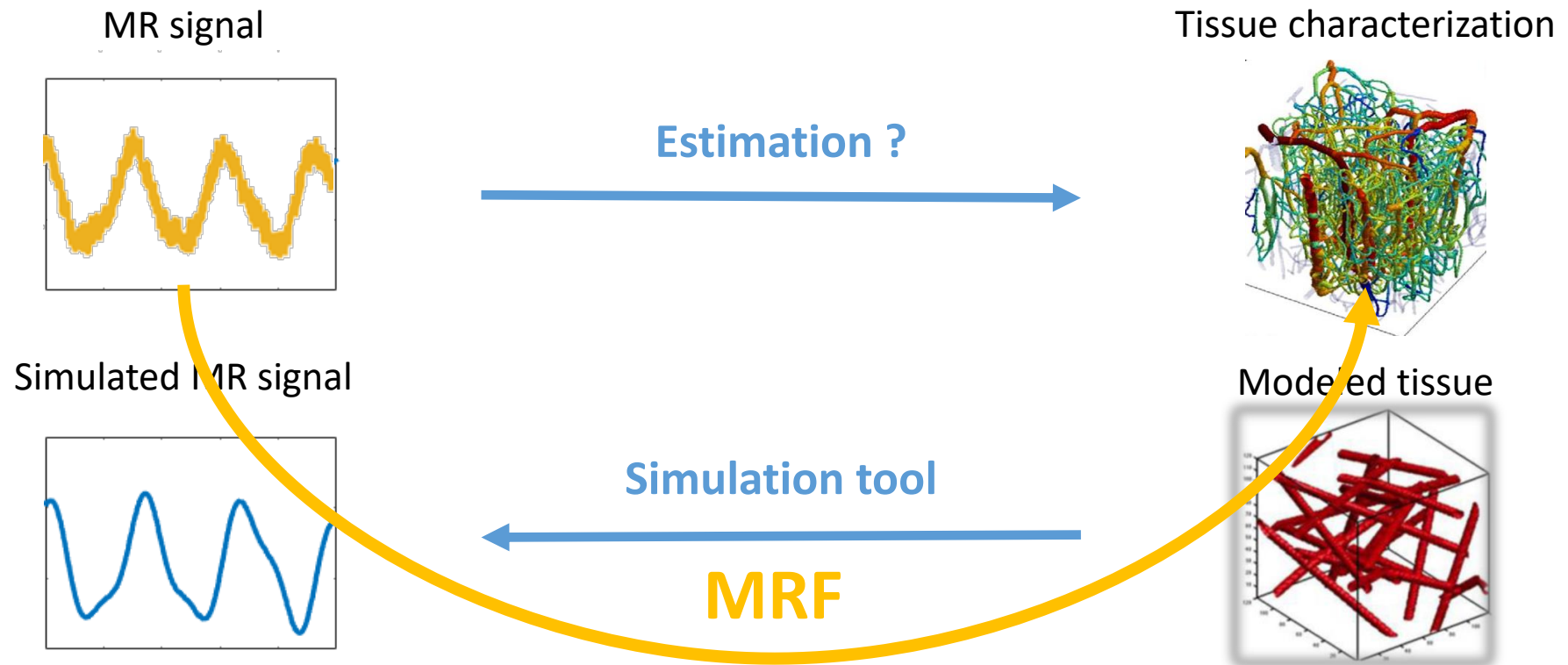
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Congrès National d'Imagerie du Vivant (CNIV) - 4th February 2019

Magnetic Resonance Fingerprinting (MRF)

Idea in the context of microvascularization



Magnetic Resonance Fingerprinting (MRF)

Principle

2-step procedure:

1. Dictionary design

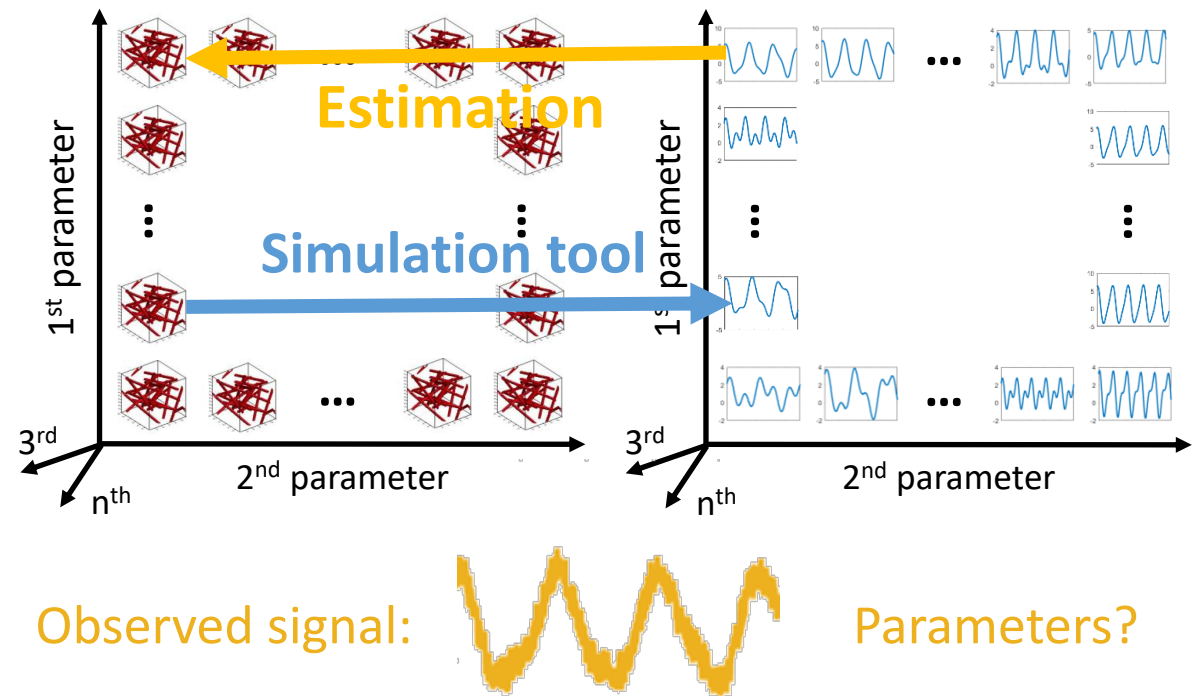
Grid formation

MR signal simulations

2. Matching procedure

Distance computations

Estimation

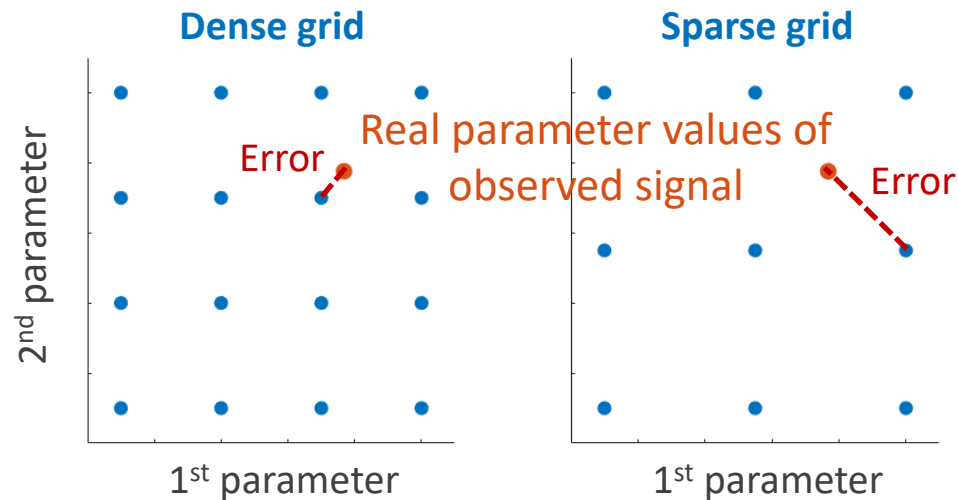


Appeal of the MRF method: **fast**, **robust**, **accurate** and **flexible**

Limitations

Complex model and time-consuming simulation

The denser the grid, the more accurate the estimates



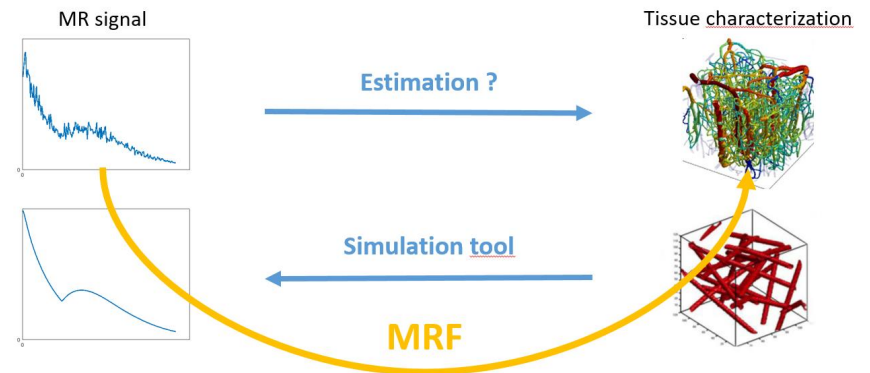
Typical dictionary size order:
 $\approx 100^{\text{Nber of parameters}}$

How to limit the growth of the dictionary while increasing the number of parameters ?

Solve the inverse problem

High-to-low regression context

Find a way to reduce the dictionary sizes (keeping the estimation accuracy of MRF)



- Nearest-neighbor methods → [D. Ma, *MRF* (2013)]
- **Dictionary learning = regression**, characteristics:
 - Nonlinear
 - From high-dimensional space to low-dimensional space

Proposed solution: regression

High-to-low regression context

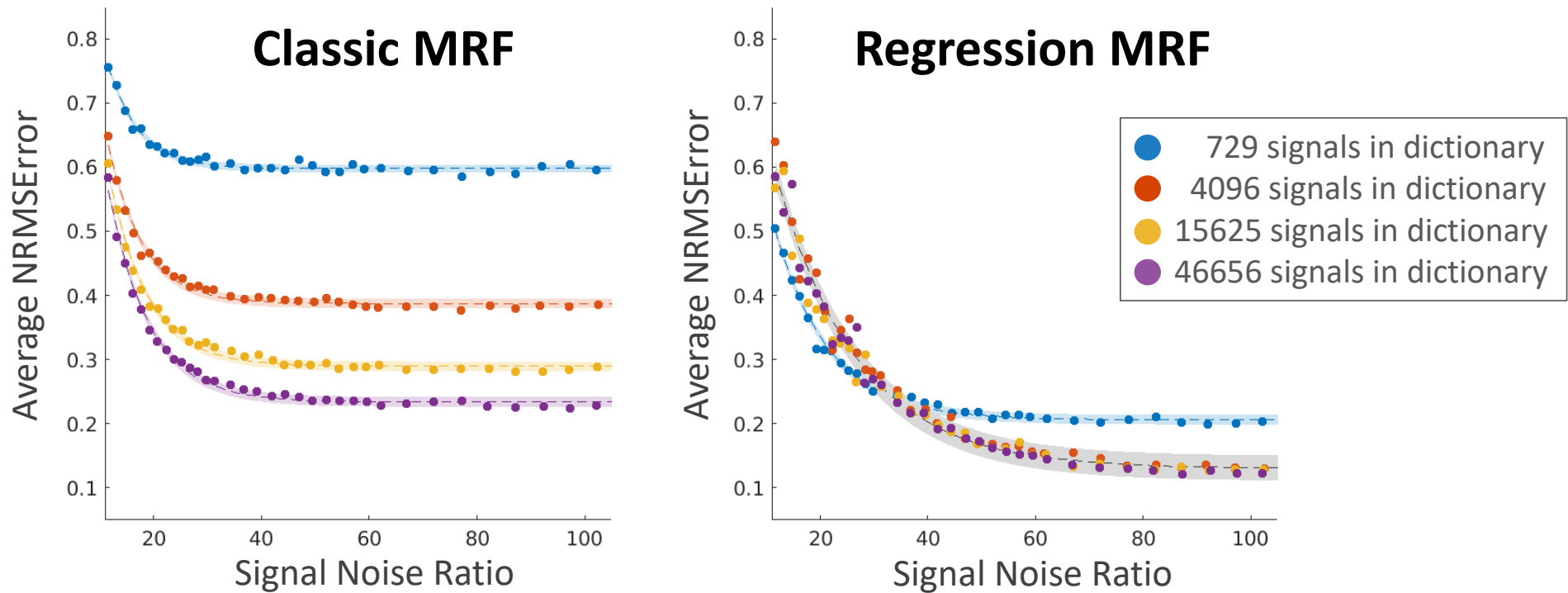
- Kernel methods and local regression → [G. Nataraj, *PERK* (2017)]
- Neural Networks → [O. Cohen, *DRONE* (2018)]
- Model inference → ***Proposed approach***

Gaussian locally-linear mapping (GLLiM)

- Solves nonlinear mapping problem automatically
- Solves the *inverse problem*, then derives the *forward model* parameters

Results

Synthetic data



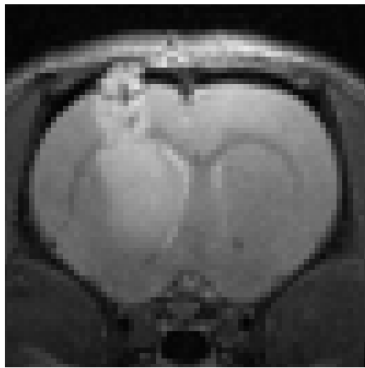
Extremely fast and accurate estimation of 6 parameters while reducing the dictionary size by a factor > 60

Results

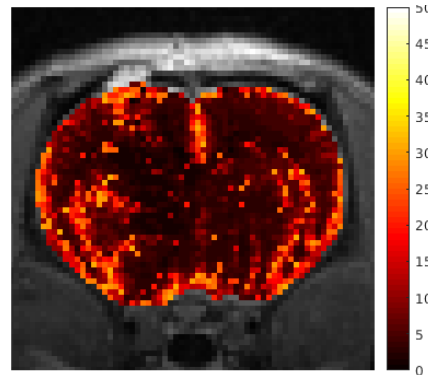
Real data

Blood Volume fraction maps (%)

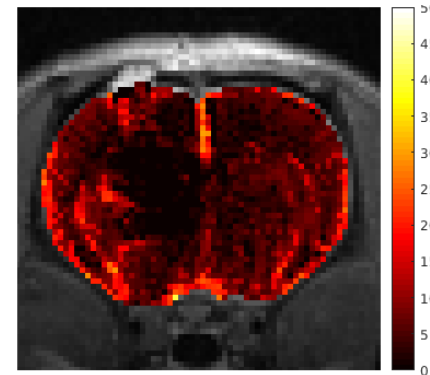
Anatomical image



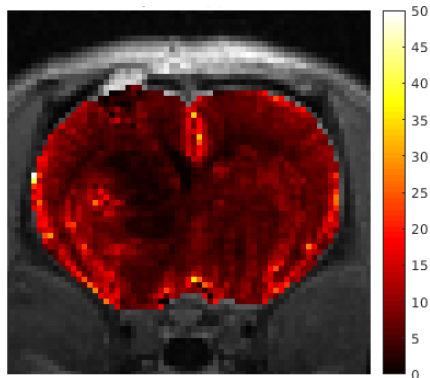
Classic MRF estimates (10^5 signals)



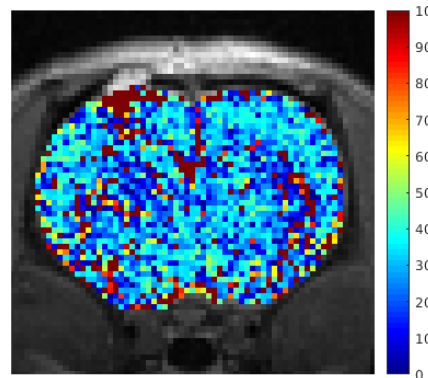
Regression MRF estimates (10^4)



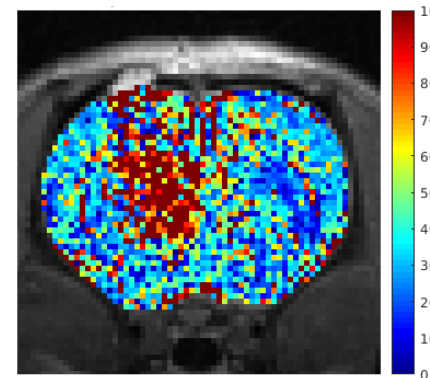
Analytical approach



Relative differences (%)



Relative differences (%)

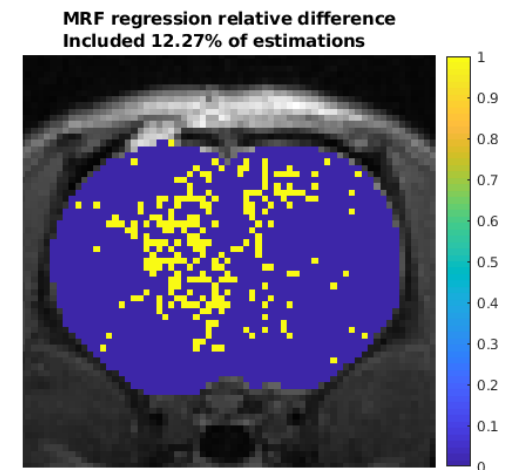
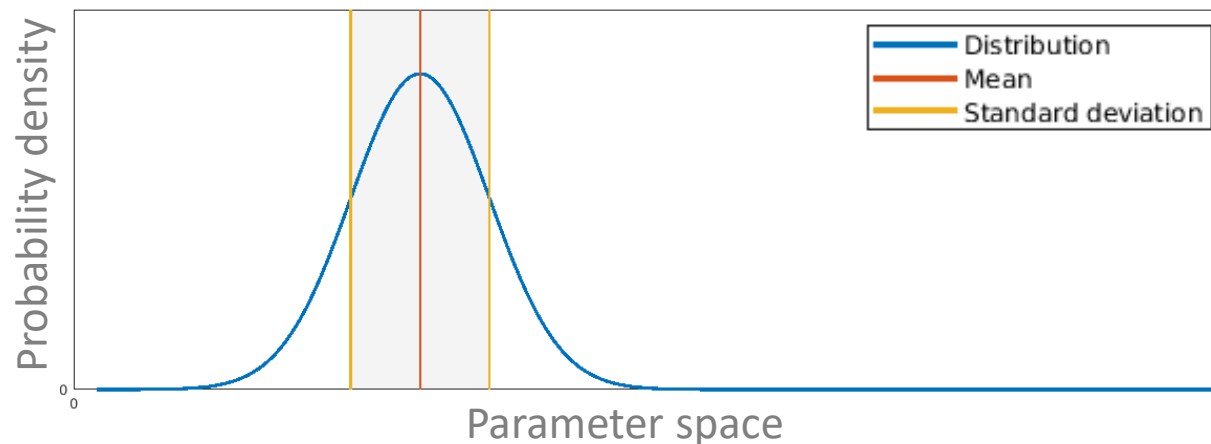


Results

Confidence index

GLLiM has the advantage to provide a full posterior distribution, from this distribution we compute:

- the **mean** to obtain the **parameter estimation**
- the **standard deviation** to obtain a **confidence index** related to



Summary

Previous and future works

- Very fast computation of estimates
- Important dictionary size reduction factor
- Accurate estimates (both on synthetic and real data)

Work not presented:

- Dictionary conception

Future work:

- Compare with neural network regressions
- Validate results with histology

References

MRF methods:

- Ma, Dan, et al., Magnetic resonance fingerprinting, *Nature* (2013)
- Nataraj, Gopal, Jon-Fredrik Nielsen, and Jeffrey A. Fessler, *Dictionary-free mri parameter estimation via kernel ridge regression*, ISBI (2017)
- Cohen, Ouri, Bo Zhu, and Matthew S. Rosen, *MR fingerprinting Deep RecOnstruction NEtwork (DRONE)*, MRM (2018)

Simulation tool:

- Pannetier, Nicolas Adrien, et al., *A simulation tool for dynamic contrast enhanced MRI*, PloS one (2013)

Regression:

- Deleforge, Antoine, Florence Forbes, and Radu Horaud, *High-dimensional regression with gaussian mixtures and partially-latent response variables*, *Statistics and Computing* (2015)

Data:

- Lemasson, B., et al., MR vascular fingerprinting in stroke and brain tumors models, *Scientific reports* (2016)

Thank you for listening



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