Dictionary learning via regression: vascular MRI application

Fabien Boux, Florence Forbes, Julyan Arbel, Emmanuel Barbier

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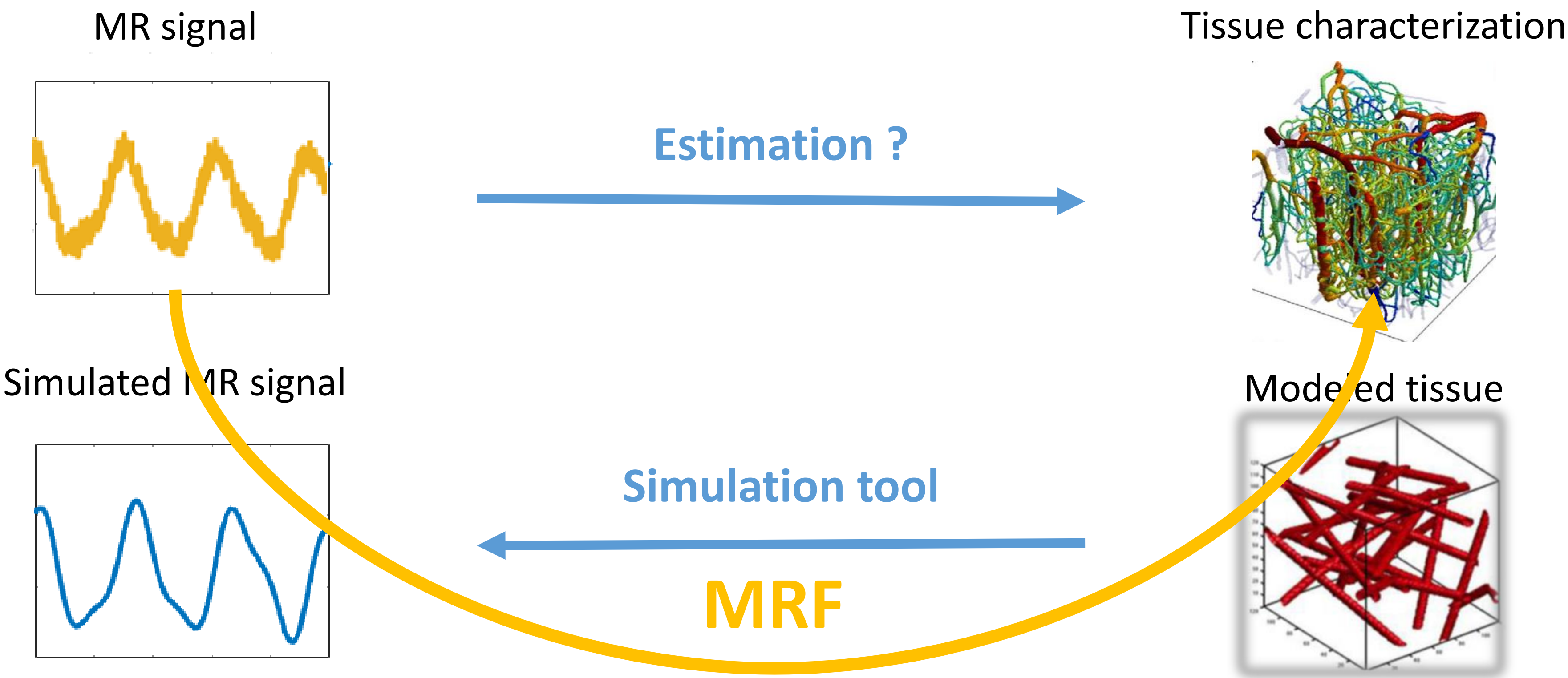
Magnetic Resonance Fingerprinting (MRF)

Idea in the context of microvascularization



Ma, Dan, et al., *Magnetic resonance fingerprinting,* Nature (2013)

Magnetic Resonance Fingerprinting (MRF)

Principle

2-step procedure:

1. Dictionary design

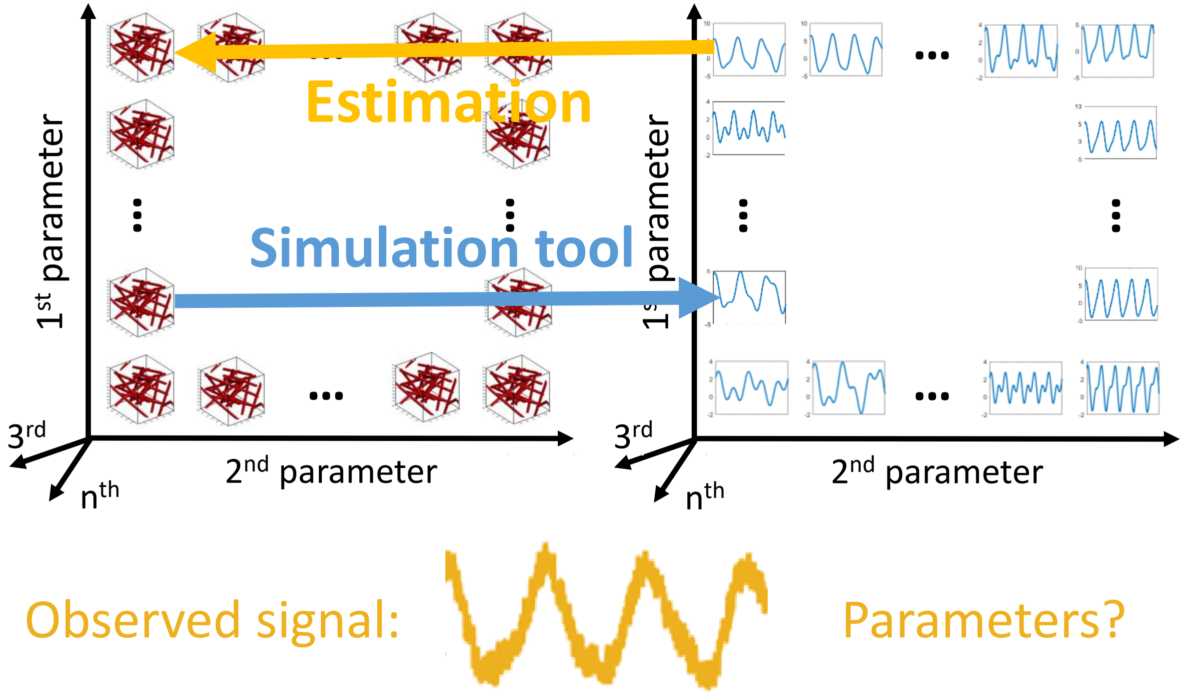
Grid formation

MR signal simulations

2. Matching procedure

Distance computations

Estimation



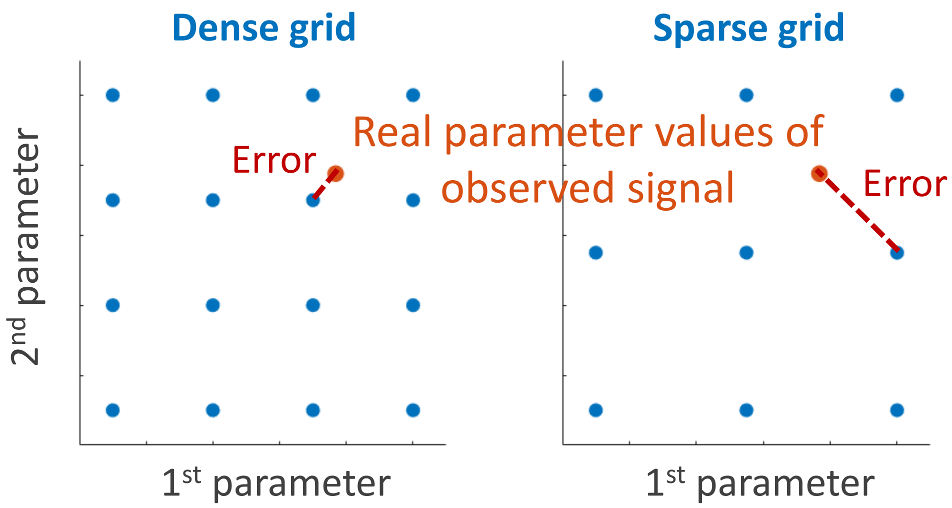
Appeal of the MRF method: **fast**, **robust**, **accurate** and **flexible**

Ma, Dan, et al., *Magnetic resonance fingerprinting,* Nature (2013)

Limitations

Complex model and time-consuming simulation

The denser the grid, the more accurate the estimates



Typical dictionary size order:

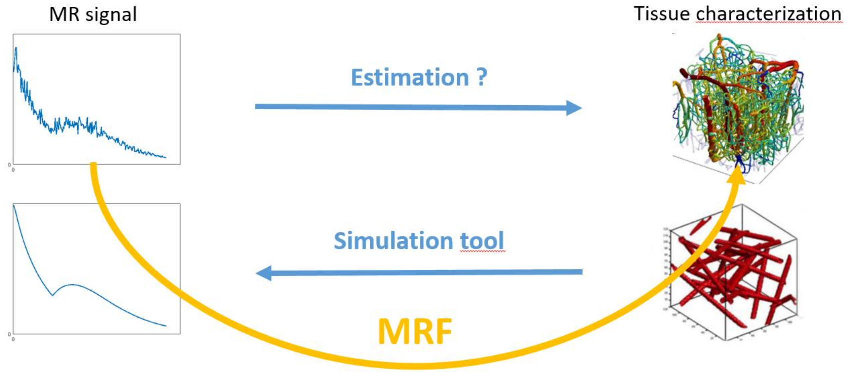
$\approx 100^{\text{Nber of parameters}}$

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***

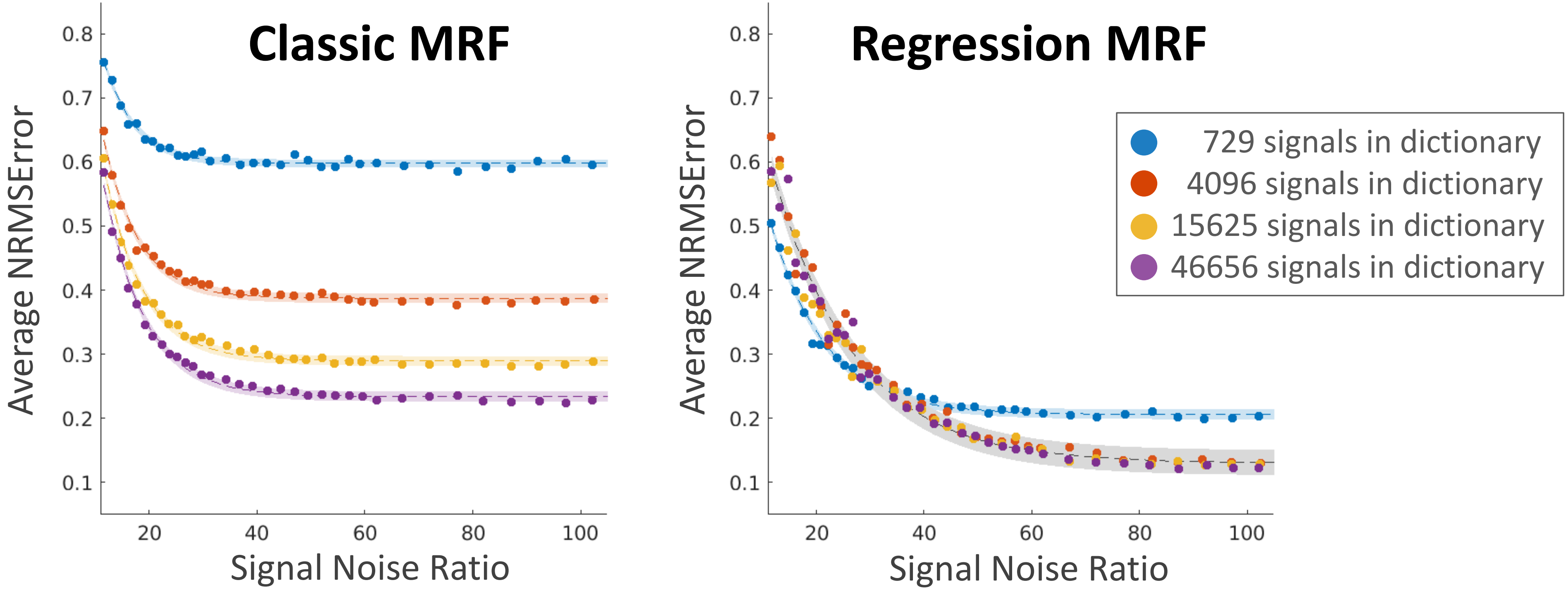
Gaussian locally-linear mapping (GLLiM)

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

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

Results

Synthetic data



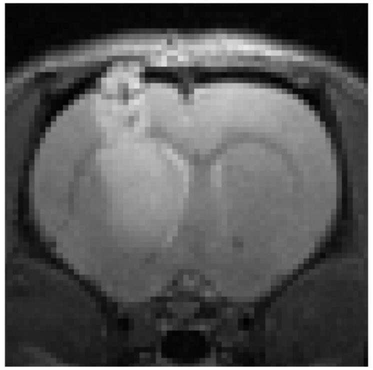
Extremely fast and accurate estimation of 6 parameters while reducing the dictionary size by a factor > 60

Results

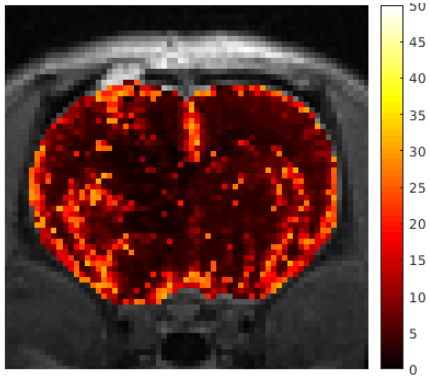
Real data

Blood Volume faction maps (%)

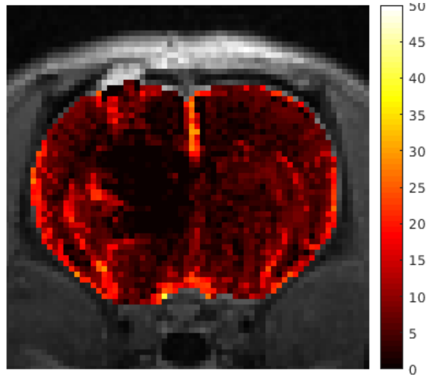
Anatomical image



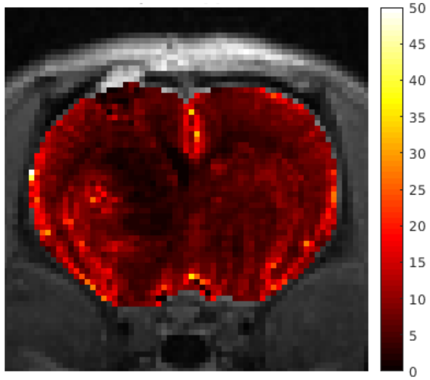
Classic MRF estimates (10^5 signals)



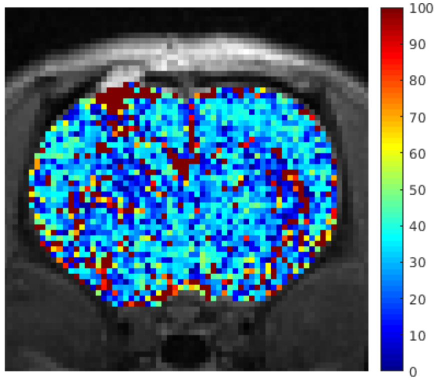
Regression MRF estimates (10^4)



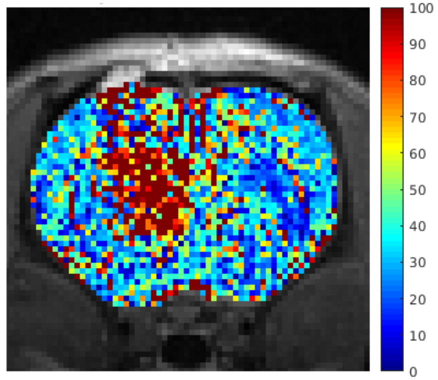
Analytical approach



Relative differences (%)



Relative differences (%)

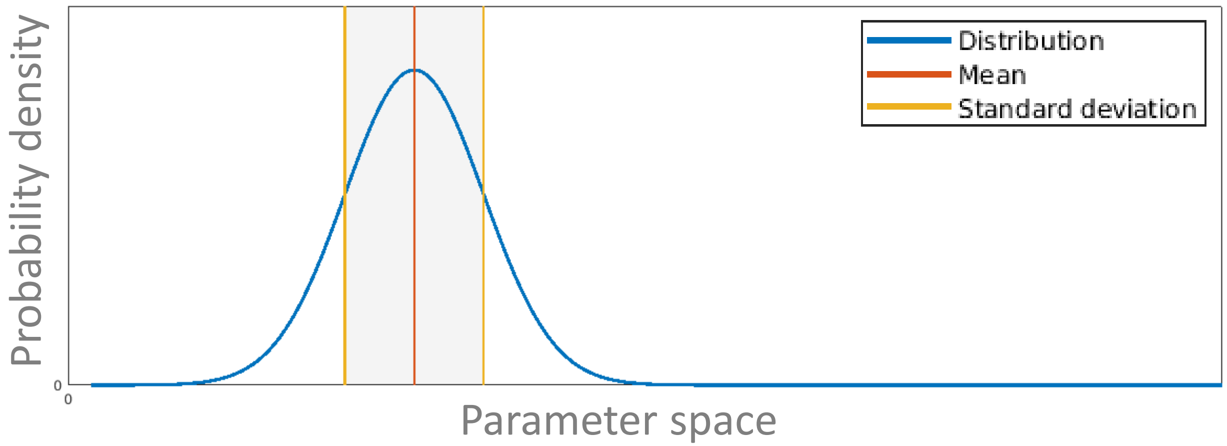


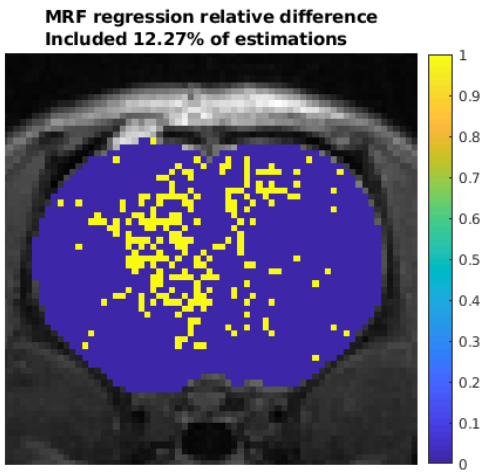
Results

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 synthetical 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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