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Dictionary learning via regression: vascular MRI application

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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:
\[ \approx 100^{\text{Number of parameters}} \]

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 $\rightarrow$ [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

Anatomical image

Blood Volume faction maps (%)

Analytical approach

Relative differences (%)

Classic MRF estimates (10^5 signals)

Relative differences (%)

Regression MRF estimates (10^4)
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:

Data:
Thank you for listening

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