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

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

Classical MRF

Regression MRF

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

![Parameter space distribution graph]

![MRF regression relative difference image]
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:
- Nataraj, Gopal, Jon-Fredrik Nielsen, and Jeffrey A. Fessler, Dictionary-free mri parameter estimation via kernel ridge regression, ISBI (2017)

Simulation tool:

Regression:

Data:
Thank you for listening

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