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UNIVERSITÉ DE LYON

SIEMENS Healthineers

ICIP 2017

WP-PD: Computational Imaging
System I

TIME SAMPLES SELECTION IN SPIRAL ACQUISITION FOR SPARSE MAGNETIC RESONANCE SPECTROSCOPIC IMAGING

Jabrane Karkouri[1,2], Fabien Millioz[1], Magalie Viallon[1], Rémy Prost[1] and Hélène Ratiney[1]

[1]Univ. Lyon, CREATIS; CNRS UMR5220; INSERM U1206; INSA-Lyon; UJM; Univ. Lyon 1, Villeurbanne, France,
[2]Siemens Healthineers, Saint-Denis, France

Introduction

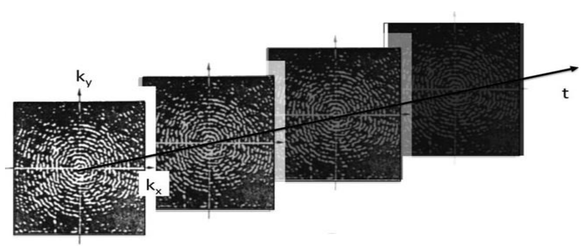


Fig 1.: Magnetic resonance spectroscopic imaging [1]: acquisition of multiple k-spaces (k space = 2D Fourier domain)

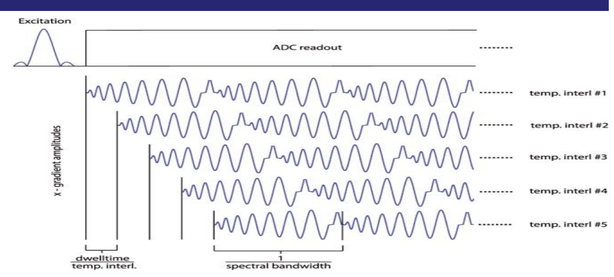
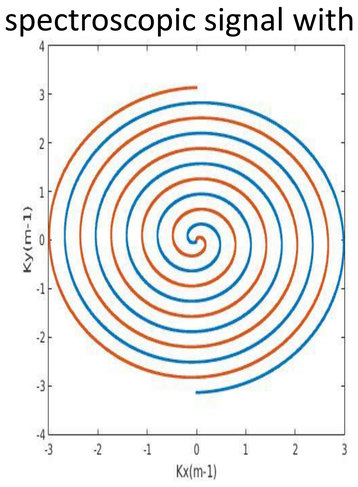


Fig 2.: Spiral MRSI sequence [2]: fast, non-cartesian k-space sampling with oscillating gradients

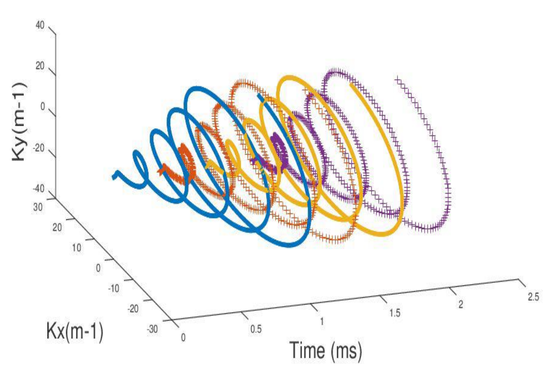
- **New fast MRSI acquisition method based on an irregular spiral k-t sampling and its application to *in vivo* spectroscopic imaging of phosphorus metabolites**

Proposed Approach

- **Implementation of spiral sampling:**
  - ✓ Spiral encoding in MRSI: one temporal point acquired for each k-space
  - ✓ Spatial and temporal interleaving in order to sample the k-space and the spectroscopic signal with the desired spatial and temporal resolution (Fig. 1).



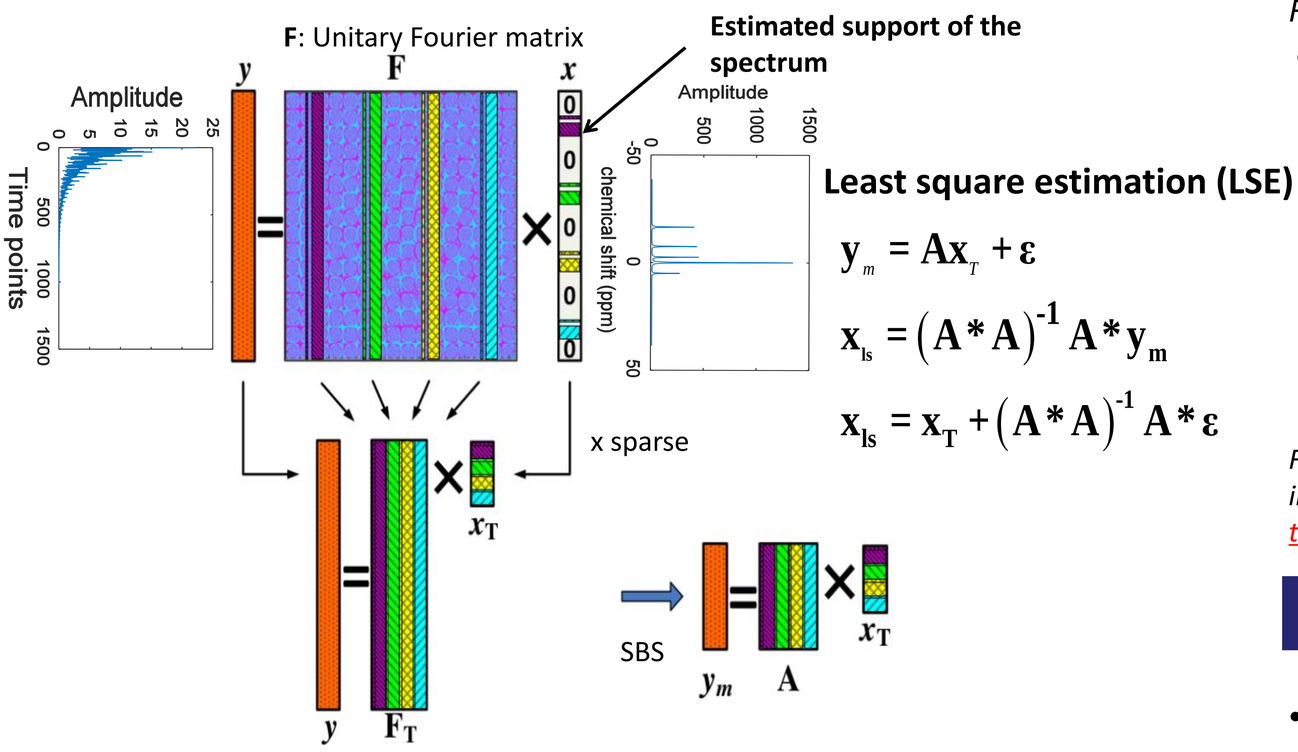
a)



b)

Fig. 3. a) Spatial (Nspat = 2), and b) temporal interleaving (Ntime = 4)

- **New spiral acquisition method based on a temporal under-sampling with a known sparse support spectrum**
- **Temporal under-sampling ➡ Decreases of the SNR**
- **Sparse reconstruction by Least-Square (LS) and noise minimization using Sequential Backward Selection of the samples (SBS)**



Least square estimation (LSE)

$$\mathbf{y}_m = \mathbf{A}\mathbf{x}_T + \boldsymbol{\varepsilon}$$

$$\mathbf{x}_{ls} = \left(\mathbf{A}^*\mathbf{A}\right)^{-1}\mathbf{A}^*\mathbf{y}_m$$

$$\mathbf{x}_{ls} = \mathbf{x}_T + \left(\mathbf{A}^*\mathbf{A}\right)^{-1}\mathbf{A}^*\boldsymbol{\varepsilon}$$

- Role of the Sequential Backward Selection of the samples (SBS) [3] = **minimize the noise amplification**

$$\mathbf{E}\left(\|\mathbf{x}_{ls} - \mathbf{x}_T\|^2\right) = \sigma^2 \mathbf{tr}\left(\left(\mathbf{A}^*\mathbf{A}\right)^{-1}\right)$$

- **Acquisition parameters**
  - ✓ Anatomic image : T2 fat sat, spatial resolution 256*256, FOV 40 cm
  - ✓ Spectroscopic image : CSI 32*32 with the phase encoding method, FOV 25cm, length time of 35minutes: data used for numerical phantom simulation, with spiral sampling

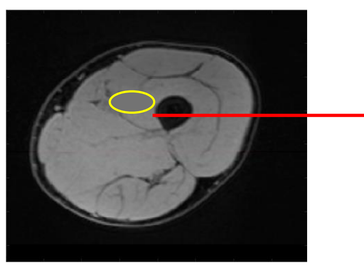


Fig. 4 : In vivo anatomic image acquired on the quadriceps of a man at 3T.

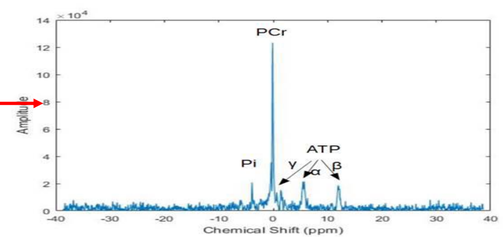


Fig. 5: Phosphorus Spectrum with 3 metabolites

- **Two methods implemented:**

Conventional spiral sampling in MRSI (method A)

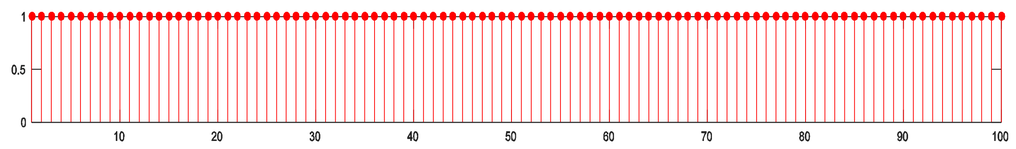
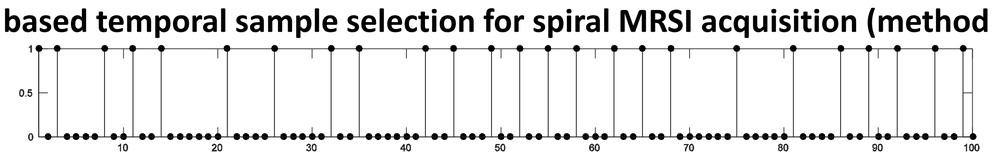


Fig. 6: One temporal point corresponds to the launch of one spiral. Time samples acquired if 1, not acquired if 0. It takes 4 excitations in the conventional case to acquire all the temporal points with a spiral length time of 1ms.

SBS based temporal sample selection for spiral MRSI acquisition (method B)



SBS temporal points selection

Fig. 7: One temporal point corresponds to the launch of one spiral. Time samples acquired if 1, not acquired if 0. It takes 2 excitations in our acquisition proposal to acquire all the temporal points with a spiral length time of 1ms.

- Simulation of our method (B) using real acquired data: **gain of acquisition time of 2**

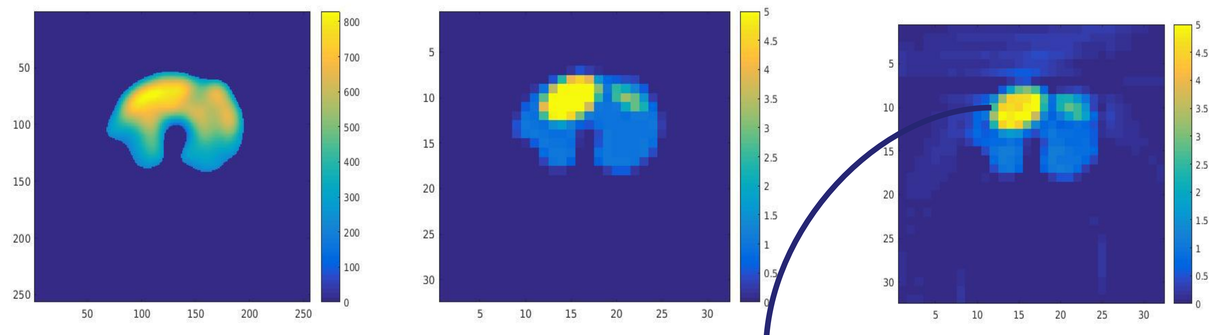
Results

- **Signal Reconstruction to Error Ratio (SRER) (std noise 10% PCr)**

$$SRER = 20\log\left(\frac{\|\,original\_spectrum\,\|_{L_2}}{\|\,original\_spectrum - reconstructed\_spectrum\,\|_{L_2}}\right)$$

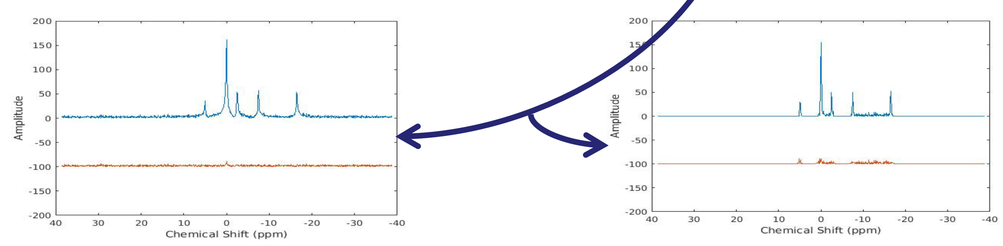
Method	A (without noise)	B (without noise)	A (with noise)	B (with noise)
SRER (dB)	25.8	24.9	23.6	19.8

- **Acquisition time reduced by a factor 2**



a) b) c)

Fig. 8: For t=0, a) In vivo 31P image at 3T b) Phantom (based on in vivo image) ; c) Reconstructed image with a gridding algorithm [5]



Using conventional uniform time sampling

SBS based irregular time sampling

Fig. 9: Magnitude of the reconstructed spectrum (noise 10% PCr) of a voxel in the left ellipse of the image (fig.4) for the two methods. The reconstruction error magnitude (shifted by -100) is given on the bottom.)

Discussion and Conclusion

- **New fast irregular acquisition method** with the use of **Compressed Sensing** demonstrated with a **Least Square reconstruction** and the **SBS algorithm**

References

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[5] J. Fessler, *Image Reconstruction Toolbox*, https://web.eecs.umich.edu/~fessler/code

Acknowledgment : ANR-11-LABX-0063/ ANR-11-IDEX-0007 and Siemens Healthineers

Contact : *www.creatis.insa-lyon.fr* jabrane.karkouri@creatis.insa-lyon.fr

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