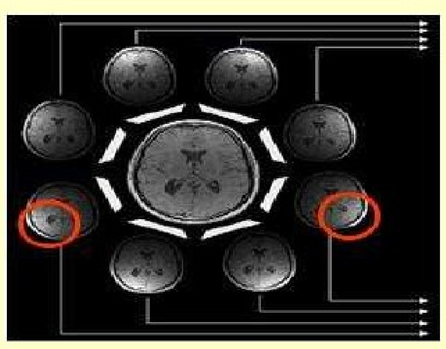
Impact of the parallel imaging reconstruction algorithm on the statistical sensitivity in fMRI

Lotfi Chaâri [1,2], Sébastien Mériaux[1], Jean-Christophe Pesquet[2], Philippe Ciuciu[1]
[1]Neurospin/CEA, France – [2]Université Paris-Est, France

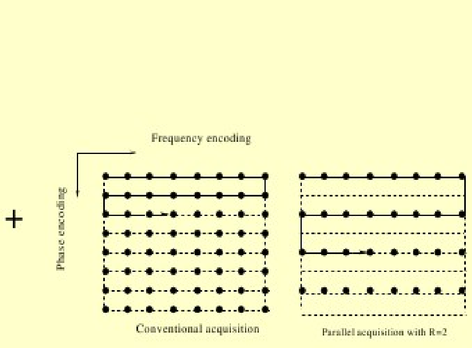
Introduction

Parallel imaging aims at reducing acquisition time in clinical applications or at improving spatial or temporal resolution. At 3 Tesla, parallel imaging is only useful in reception, ie at the reconstruction step using multi-channel coils. Sensitivity Encoding (SENSE) [1] methods have been developed as a powerful tool to reconstruct a full Field of View (FoV) image from multiple k-space under sampled images acquired on separate channels. SENSE methods suffer from strong artifacts when high values of acceleration factors are considered in the parallel imaging setup. Regularized reconstruction methods are helpful in such circumstances. Here, on Echo Planar Imaging (EPI) fMRI data, we compare a recent wavelet-based regularized parallel imaging reconstruction algorithm [2] with the SENSE approach in terms of statistical sensitivity. This comparison takes place at the subject level for high in-plane spatial resolution (2x2 mm2) and for two different acceleration factors (R=2 and R=4).

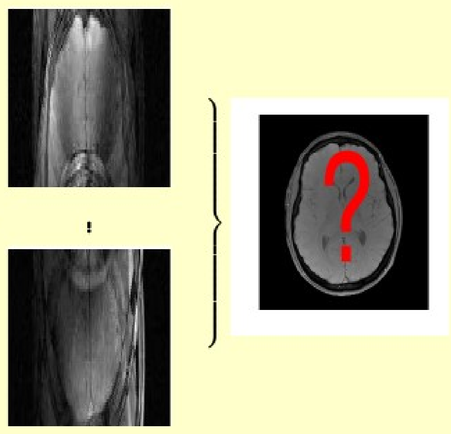
Method



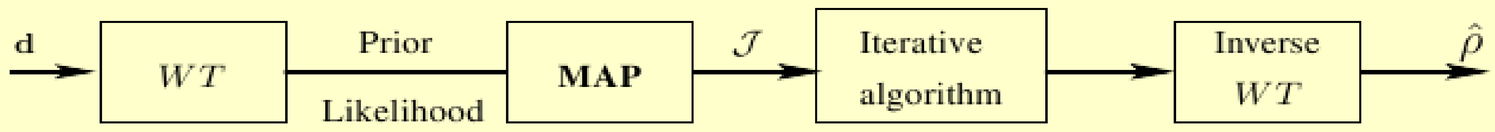
Multiple receiver coils with complementary sensibility profiles



Subsampling the k-space along the phase encoding direction



Observation model: $\mathbf{d} = \mathbf{S}\rho + \mathbf{n}$

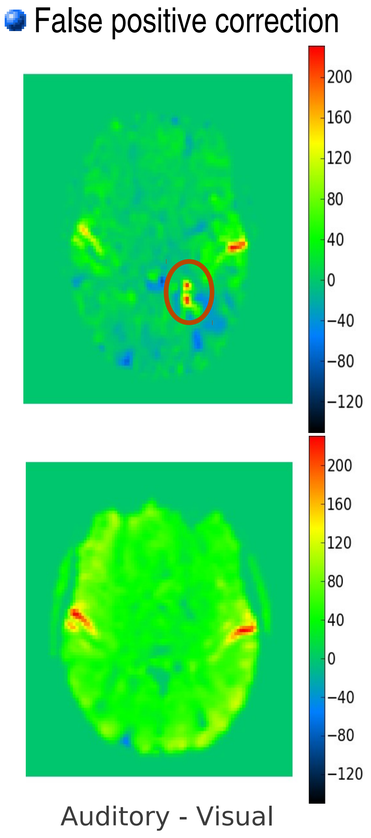
SENSE[1]	Wavelet Transform regularization [2]
$\hat{\rho} = \arg\min_\rho \|\mathbf{d} - \mathbf{S}\rho\|^2_{\Psi^{-1}}$ $= [\mathbf{S}^H\Psi^{-1}\mathbf{S}]^{-1}\mathbf{S}^H\Psi^{-1}\mathbf{d}$	

Data

The fMRI data were recorded at 3 T (Siemens Trio) using a gradient-echo EPI sequence (TE=30ms/TR=2400ms/slice thickness=3mm/transversal orientation/FOV=192mm^2) during a cognitive localizer experiment designed to map auditory, visual and motor brain functions as well as higher cognitive tasks such as number processing and language comprehension. It consisted of a single session of N=125 scans lasting TR=2.4s each. The paradigm was a fast event-related design comprising sixty auditory, visual and motor stimuli, defined in ten experimental conditions (auditory and visual sentences, auditory and visual calculations, left/right auditory and visual clicks, horizontal and vertical checkerboards). A 32 channel surface coil was used to enable parallel imaging. Hence, for all the 22 subjects, fMRI data were collected at different in-plane spatial resolutions (3x3, 2x2 and 1.5x1.5 mm^2) while maintaining the TR-value constant. The mSENSE parallel imaging reconstruction algorithm available on the Siemens Workstation was used for the two high resolution sequences with varying acceleration factors R. At the 2x2 mm^2 resolution, fMRI data were collected using R=2 and R=4 while at 1.5x1.5mm2 R=4 was the sole value that makes possible whole brain data acquisition in the specified TR was R=4. Our Wavelet regularized algorithm (WRSENSE) has been then used to reconstruct raw data on which a statistical analysis was conducted to evaluate the effect of the regularized reconstruction on the statistical sensitivity in fMRI.

Comparison results in fMRI

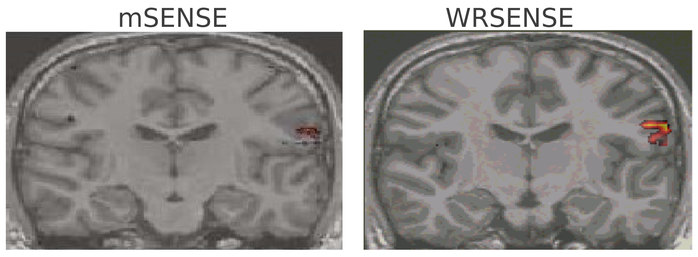
- False positive correction

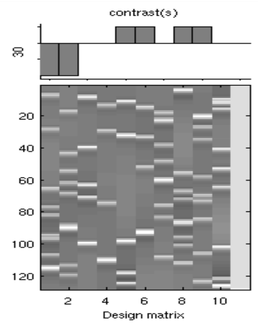


Auditory - Visual

- Improved statistical sensitivity

R = 2





Video - Checkerboard

R = 4

Statistics: *p-values adjusted for search volume*

set-level		cluster-level			voxel-level					mm mm mm	
p	c	$p_{corrected}$	k_E	$p_{uncorrected}$	$p_{FWE-corr}$	$p_{FDR-corr}$	T	$(Z_=)$	$p_{uncorrected}$		
1.000	55	0.000	103	0.000	0.000	0.000	6.33	5.84	0.000	-64	-16 24
					0.005	0.001	5.73	5.36	0.000	-56	-16 27
					0.154	0.005	4.97	4.71	0.000	-64	-10 15
		0.004	34	0.000	0.001	0.000	6.23	5.76	0.000	-30	-82 -12
					0.995	0.042	4.22	4.06	0.000	-40	-82 -6

WRSENSE

Statistics: *p-values adjusted for search volume*

set-level		cluster-level			voxel-level					mm mm mm	
p	c	$p_{corrected}$	k_E	$p_{uncorrected}$	$p_{FWE-corr}$	$p_{FDR-corr}$	T	$(Z_=)$	$p_{uncorrected}$		
1.000	50	0.001	42	0.000	0.000	0.000	6.85	6.25	0.000	-30	-84 -12
					0.996	0.112	4.24	4.07	0.000	-40	-84 -6

mSENSE

Statistics: *p-values adjusted for search volume*

set-level		cluster-level			voxel-level					mm mm mm	
p	c	$p_{corrected}$	k_E	$p_{uncorrected}$	$p_{FWE-corr}$	$p_{FDR-corr}$	T	$(Z_=)$	$p_{uncorrected}$		
0.910	149	0.082	12	0.001	0.000	0.000	6.42	5.92	0.000	-42	-70 -12
		0.000	89	0.000	0.001	0.000	6.21	5.75	0.000	-52	-16 27
					0.001	0.000	6.13	5.68	0.000	-62	-18 21
		0.002	22	0.000	0.028	0.002	5.36	5.05	0.000	2	-70 48
					1.000	0.035	4.18	4.02	0.000	6	-78 42
		0.000	35	0.000	0.127	0.006	5.01	4.75	0.000	-44	14 15
					1.000	0.033	4.22	4.05	0.000	-46	8 24
		0.001	23	0.000	0.451	0.011	4.71	4.49	0.000	-52	-28 57
					1.000	0.042	4.05	3.91	0.000	-46	-22 51
		0.001	23	0.000	0.669	0.013	4.61	4.41	0.000	-30	-58 42
		0.000	43	0.000	0.808	0.014	4.57	4.36	0.000	-50	2 33
					0.981	0.018	4.49	4.29	0.000	-52	6 42
		0.002	22	0.000	0.984	0.018	4.47	4.28	0.000	24	-102 3
					1.000	0.049	3.98	3.84	0.000	18	-100 12

Statistics: *p-values adjusted for search volume*

set-level		cluster-level			voxel-level					mm mm mm	
p	c	$p_{corrected}$	k_E	$p_{uncorrected}$	$p_{FWE-corr}$	$p_{FDR-corr}$	T	$(Z_=)$	$p_{uncorrected}$		
0.960	128	0.007	21	0.000	0.001	0.000	6.20	5.74	0.000	-4	2 57
		0.000	51	0.000	0.002	0.001	5.92	5.51	0.000	-62	-22 21
		0.000	48	0.000	0.028	0.003	5.37	5.06	0.000	-56	4 33
					0.842	0.018	4.56	4.36	0.000	-56	2 42
					1.000	0.073	3.93	3.79	0.000	-52	10 45
		0.000	40	0.000	0.273	0.011	4.84	4.60	0.000	-50	12 15
		0.002	25	0.000	0.978	0.023	4.47	4.28	0.000	-54	-56 -3

Conclusion

- Gain in **statistical sensitivity**
  - Less false positives
  - Better detection of activated area
- To be confirmed and validated on a **group-level analysis**
- Extensions: **3D and 4-D reconstructions**

References

[1] K. P. Pruessmann, M. Weiger, M. B. Scheidegger, P. Boesiger, SENSE : sensitivity encoding for fast MRI, Magnetic Resonance in Medicine 42 (5) (1999) 952–962.

[2] L. Chaari, J.-C. Pesquet, Benazza-Benyahia and P. Ciuciu, Autocalibrated parallel MRI reconstruction in the wavelet domain,ISBI 2008, Paris, France, 2008, pp. 756–759.

16th Annual Meeting of the Organization for Human Brain Mapping - June 6-10, 2010, Barcelona, Spain.