# Fast in vivo susceptibility imaging using compressed sensing and parallel imaging

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**Introduction** Quantitative susceptibility mapping may be calculated using image phase information, which is usually obtained using a 3D SPGR sequence. Due to the long TE used and line-by-line sample acquisition nature, data acquisition covering the entire brain volume is a considerably long process. In this work, we set to shorten the scan time by reducing data acquisition and apply a novel image reconstruction method that exploits the complementary properties of parallel imaging (pMRI) and compressed sensing (CS).

**Theory** The proposed image reconstruction consists of two parts: CSSENSE (1) and prior estimate based compressed sensing (PECS) (2). CSSESE exploits the complementary operational nature of CS and pMRI: CS removes aliasing by exploiting the smoothness of the underlying image; parallel imaging separates the folded pixels by utilizing distinctive coil sensitivity weighting. PECS exploits the complementary reconstruction characteristics of CS and pMRI: pMRI gives accurate image estimate but is often impaired with high level of noise amplification; CS reconstruction is noise stable but may have a lack of image contrast and details. We further combine the above two methods, and the flow chart diagram of the proposed method is shown in Fig.1(a).

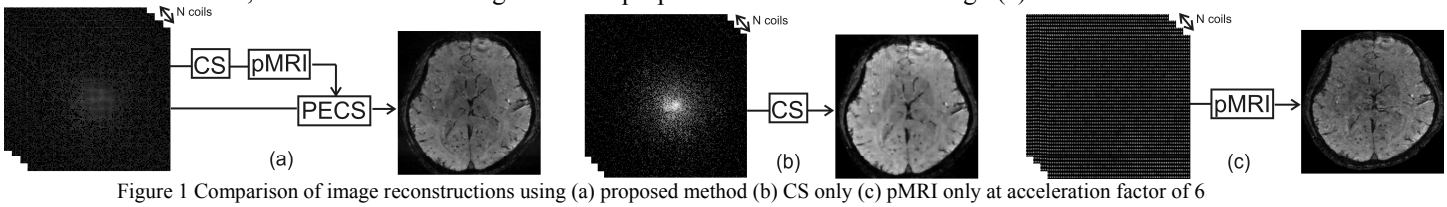


Figure 1 Comparison of image reconstructions using (a) proposed method (b) CS only (c) pMRI only at acceleration factor of 6

The sampling pattern to be used is illustrated on the left of Fig.1(a), i.e. k-space sample sets that correspond to a reduced FOV image is further under-sampled using a CS-like random sampling strategy. In the reconstruction, firstly a CS reconstruction is made for each individual coil to recover a set of reduced FOV images; then pMRI is used to restore the full FOV images which are often corrupted with reconstruction noise and other artifacts. These intermediate images from pMRI are then taken *a priori* in the following PECS step to give a final reconstruction. The advantage of the proposed method comparing to using pMRI or CS alone can be seen in the comparison of image reconstructions made at an acceleration factor (AF) of 6 shown in Fig.1: image reconstructed using CS alone shows blurry features whereas the that obtained using pMRI alone is corrupted by reconstruction noise; the proposed method led to a reconstructed image with well preserved image details as well as a low noise profile.

**Method** In vivo brain imaging of a healthy adult volunteer was performed on a 3T scanner equipped with an 8-channel head coil. A 3D SPGR sequence was used with the following parameters: FOV = 256×256×180 $mm^3$, matrix = 256×256×180, TE/TR = 40/60 ms, flip angle = 20º. The entire scan took 48 minutes. Full k-space data set was acquired that allows the k-space under-sampling to be simulated in the post-processing. Reconstruction of the complex data sets at various acceleration factors are performed using the above-mentioned method. Image phase are extracted from the reconstructed complex data set and is processed with phase unwrapping and background phase removal as suggested in (3), susceptibility mapping was then calculated using the obtained phase maps with the pre-conditioned iterative method as described in (4).

**Results and discussion** The axial slices of calculated susceptibility map using reconstructed data sets at AF of 1 (full data set) and AF of 8 are shown in Fig.2, it is seen that the visual image features are well preserved despite the high AF used. Further quantitative comparisons are made by calculating the relative susceptibilities of the selected iron-rich regions by using the susceptibility of CSF regions as a reference, and the results are plotted against the various acceleration factors on the right of Fig.2. It is seen that the calculated susceptibility values are fairly stable until AF of 6, then it drops considerably at AF of 8. This is because at high level of under-sampling, CS reconstructions may cause slight loss of image contrast, whereas the relative susceptibility used is a measure of image contrast.

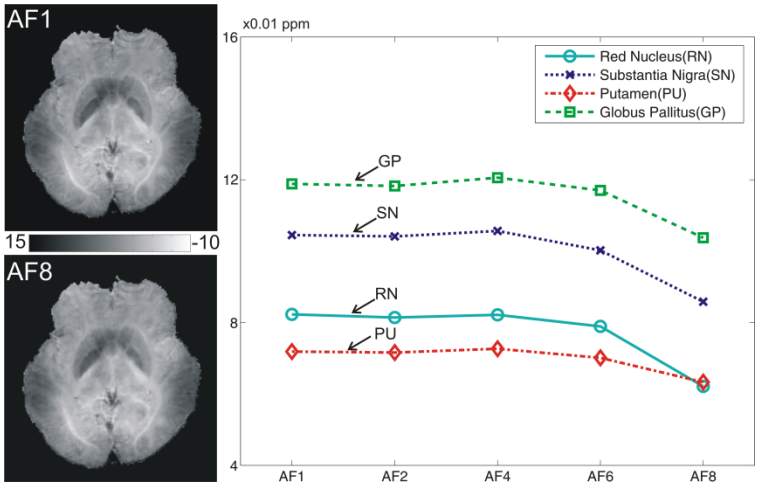


Figure 2 Calculated susceptibility values (x0.01ppm) at different AFs

**Conclusion** We have shown by using a novel image reconstruction method which exploits the complementary properties of pMRI and CS, qualitatively and quantitatively accurate susceptibility maps may be obtained at a AF of 6, which allows a scan using a standard SPGR sequence with TE of 40ms and 1mm isotropic whole brain coverage to be completed within 8 minutes.

**Reference** (1) Liang, et al. MRM, 2009. (2) Wu, et al. MRM 2010.
(3) Schweser, et al. Neuroimage 2010. (4) Rochefort, et al. MRM 2010.