Adaptive synthesis of prior image and new acquired data in repetitive 3D examinations

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Introduction: High resolution isotropic 3D MR imaging is often repeatedly performed in therapeutic follow-up, preoperative evaluation and postoperative follow-up. For comparability the same sequence with identical parameters is used in these repetitive examinations. Parallel imaging often combined with Compressed Sensing (CS) is applied to reduce the long acquisition time of 3D MRI to a clinical acceptable range [1], where *k*-space is usually highly undersampled. However, if the undersampling is beyond the information redundancy promoted by parallel imaging or by CS, strong aliasing artifacts can be observed in the reconstructed image. From the point of view of information content very little change occurs between successive examinations. Therefore and based on similar concepts developed for dynamic imaging [2], we present a framework, which explores the information redundancy in temporal domain in longitudinal examinations by adaptively synthesizing the prior data and the new acquired data from separate 3D examinations. It demonstrates that the information synthesis can help to reduce the level of residual aliasing artifacts when the *k*-space undersampling is beyond the possible acceleration of Compressed Sensing.

Method: The framework is shown in Fig.1. In each repetitive examination, *k*-space is strongly undersampled. A coarse new image is reconstructed by CS algorithm using only the acquired data. Bulk motion and pose change of the object between separate examinations is corrected by aligning prior image to coarse new image using intensity-based image registration [3]. To eliminate the low-resolution difference between the prior image and the new image, which is introduced by i.e. the change of coil sensitivities, profile replacement is performed by$\mathrm{I_e^i} = \mathrm{I_r}\,\mathrm{P_0^i}/\mathrm{P_r}$, here $\mathrm{P_0^i}$ is the profile of the coarse new image in the i^{th} channel; $\mathrm{P_r}$ is the profile of the aligned prior image; $\mathrm{I_e^i}$ is the obtained estimate of new image in the i^{th} channel. Profiles are extracted by a low-pass filter, which extracts the central portion of *k*-space, where the overall sampling factor is above a threshold *h*. *h* is empirically set to 0.6 in our experiments. The estimate of the new images in each channel is converted to *k*-space data and further undersampled by the identical sampling pattern used in the new examination to obtain the estimate of new *k*-space data. Image difference is reconstructed by CS using the *k*-space difference obtained by subtracting the estimate of the new *k*-space data from the acquired new *k*-space data. A weighting map is calculated from the image difference by performing low-pass filtering on the image difference, and inversion of its signal intensities. The coarse new images and the estimate of the new images are adaptively combined channel by channel with the formula $\mathrm{I_s^i} = \mathrm{I_0^i}(1-\mathrm{W}) + \mathrm{I_e^i}\mathrm{W}$, here *W* is the weighting map; $\mathrm{I_0^i}$ is the coarse new image in i^{th} channel; $\mathrm{I_s^i}$ is the synthesized image. The method has been tested on volunteers and patients. As an example the brain examinations of a patient before and after surgery is shown: the prior image was acquired on a 3T scanner (MAGNETOM Trio A Tim System, Siemens, Erlangen) using 3D MPRAGE with the following parameters: image matrix = [160 x 256 x 256] with isotropic resolution, total acquisition time 3min32sec. The 2nd examination was performed with identical parameters 4 month later. Brain surgery was performed between two examinations. The *k*-space data was further randomly undersampled offline to test our method. The total sampling factor of the 2nd examination was 12.3% of full *k*-space.

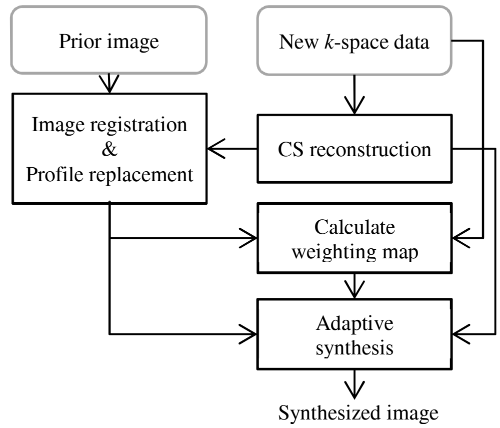

Fig.1 the framework of the adaptive information synthesis

Results & Discussion: The reconstructed new image (Fig.2b) based on the full acquisition is taken as 'standard'. The relative sum of absolute difference is used to quantify the reconstruction error, which is 11.99% in the coarse new image (Fig.2c) reconstructed by CS with only the randomly sampled *k*-space data. The reconstruction error was reduced to 11.44% in the synthesized image (Fig.2d), where the information from prior image (Fig.2a) is incorporated. In both coarse new image and the synthesized image, the changes from brain surgery were successfully depicted (see dashed arrows). Some residual aliasing artifacts from *k*-space undersampling in the coarse new image were reduced in the synthesized image, especially in regions without changes (see solid arrows). In the adaptive synthesis, a weighting map is used to avoid the introduction of erroneous signals from the prior image due to changes between the two separate examinations, or due to registration errors. The weighting map is a similarity map between the estimate and the real new image, and its accuracy improves when the sampling factor increases, so false information introduced in the synthesis will be further suppressed. The amount of information restored through the synthesis is determined by the quality of the prior image and the registration accuracy. The adaptive synthesis framework can also be employed to restore information from an incomplete acquisition which was interrupted by patient motion. The synthesized image might be used improve the compressed sensing reconstruction because the information from the prior images reduces the underlying uncertainty, and therefore promote data sparseness.

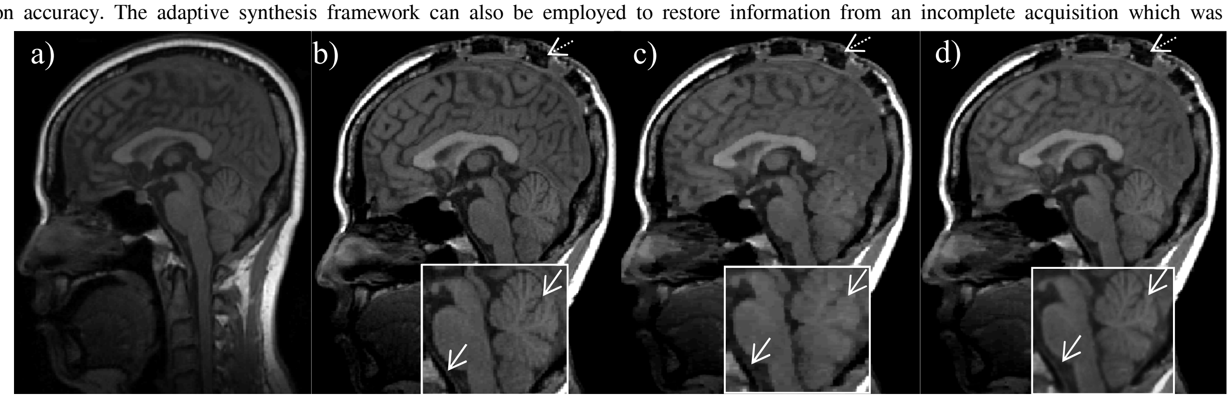

Fig.2 a sagittal slice with the same slice position in different 3D image volumes: a) aligned prior image; b) 'standard' new image; c) coarse new image reconstructed by CS with sampled data only; d) synthesized image with information from both sampled data and prior image.

References: 1. Lustig M et al, MRM 2007, 1182-1195; 2. Chen GH et al, Med Phys. 2008 Feb;35(2) 660-663; 3. Myronenko A, Technical Report, OHSU, arXiv: 0906.3323v1;