Adapted Random 3D Sampling Patterns for CE-MRA

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Introduction: Variable density 3D random sampling trajectories which were introduced in the context of compressed sensing [1] have great potential for subsampled CE-MR angiography techniques which deliver data sets with high contrast to noise ratio. The goal of this work was to present a parameter-free method to construct variable density sampling patterns which are tailored to angiography. Sampling patterns are generated with the use of a probability density function (pdf) that is constructed by using measured k-space data as a reference, which automatically ensures an appropriate distribution of sample points. It is also shown that these data sets can be used together with a nonlinear parallel imaging method [2, 3]. This combination allows the use of very high acceleration factors while still yielding images with excellent image quality.

Methods: The proposed method to generate the variable density 3D random sampling pattern is to use the scan of the same anatomic region of a different patient or a healthy volunteer as a template. Patterns that are generated this way can be pre-computed for different types of scans or anatomical regions. The template and the sampling patterns for R=30 and R=60 are displayed in **Fig. 1**.
Subsampling experiments were performed to evaluate the proposed method. A fully sampled CE-MRA data set of the carotid arteries (3D GRE, TR/TE=3.74/1.48ms, FA=30°, matrix: 448x352x40, resolution: 0.55x0.55x0.70mm^3) was acquired on a clinical 3T scanner (Siemens Magnetom TIM Trio, Erlangen, Germany). Written informed consent was obtained from all subjects prior to the examinations. Random sampling patterns were constructed with the use of a pdf that was generated using a data set from a different patient, which was acquired several weeks earlier. Acceleration factors of R=20, 30, 40, 50 and 60 were used. The data set was modulated by using measured coil sensitivities from an 8 channel head coil from the 2010 ISMRM reconstruction challenge.

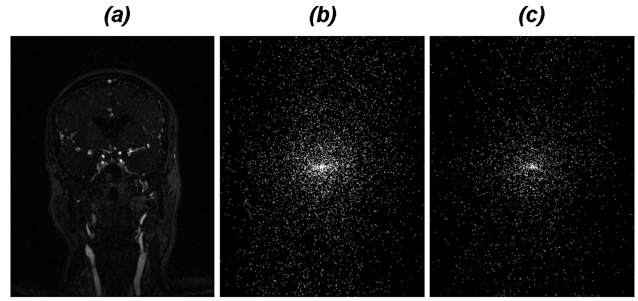

Fig. 1: (a) Template, (b) Generated random 3D sampling pattern for R=30, (c) Generated random 3D sampling pattern for R=60.

Results and discussion: Our results show that excellent image quality can be achieved even for very high acceleration factors (**Fig. 2**) without any application of temporal view sharing. For acceleration factors up to 30, only a slight decrease of SNR and a minimally reduced contrast for the smallest vessels result. If higher acceleration factors are used, it can be seen that small vessels are lost in the reconstructions. However, the SNR is still excellent considering the amount of acceleration. The RMS differences to the original fully sampled data set are displayed in **Table 1** (mean RMS and standard deviation over all 40 slices are shown).
The proposed approach ensures that the tuned ratio of low to high sampled frequencies is particularly suited to angiography scans, allowing higher acceleration factors than a fixed ratio. One major advantage is that the method is completely free of any user-defined parameters and does not require a priori choice of a mathematical model (e.g. polynomial or exponential models) for the sample distribution in k-space. Our experiments showed that the method is robust regarding the choice of the reference image, as the only information that has to be obtained is an estimate of the ratio of high to low frequency components. The exact anatomical details are not important in this context.

Acceleration	R=20	R=30	R=40	R=50	R=60
RMS Difference	0.147± 0.007	0.205± 0.013	0.271± 0.019	0.327± 0.036	0.362± 0.046

Table. 1: RMS differences to SOS reconstruction from the fully sampled reference data set for the downsampling experiments of the angiography data set. Mean value and standard deviation over all 40 slices are shown.

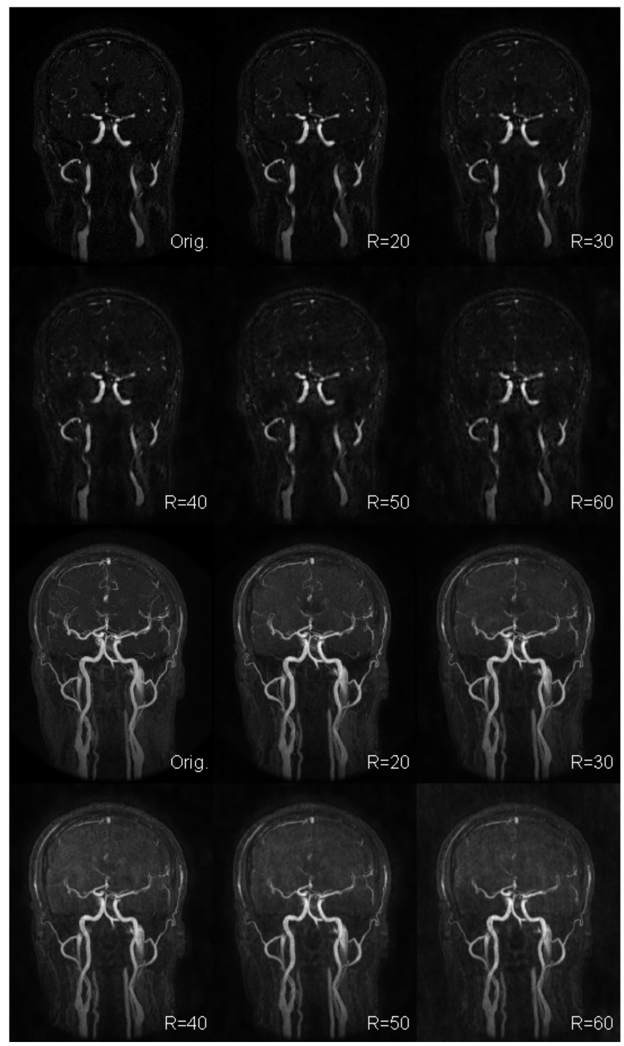

Fig. 2: Results of downsampling experiments for subsampling with R=20, 30, 40, 50 and 60.

References: [1] Lustig et al., MRM 58: 1182-1195 (2007), [2] Uecker et al., MRM 60: 674-682, [3] Knoll et al., ISMRM 2009: 2721