Moët: Multiple oscillating ëfficient trajectories

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Introduction: One important requirement of CS is incoherent sampling in k-space, which ideally is given by a variable density random sampling in Cartesian k-space [1]. This cannot be easily achieved for 2D imaging, since trajectories must follow continuous lines. One potential solution is to blip the gradients with a radial like trajectory [2] to form an oscillating trajectory. However, if one uses the same blips for every projection, a coherent sampling pattern still emerges. Here we propose a new sampling scheme consisting of multiple oscillating ëfficient trajectories (Moët). The proposed trajectories can be implemented on standard clinical scanners and provide an improved PSF for 2D CS applications.

Materials and Methods: One example Moët trajectory is shown in Fig. 1. Generally, Moët is a combination of radial sampling modified to cover the full square-shaped k-space with oscillating trapezoidal gradients of varying amplitude orthogonal to the readout direction. Since the diagonals are the longest distance, Moët samples these along straight lines without oscillations to achieve maximal time efficiency. For other projections, the necessary distance to cover and thus the readout gradient strength is smaller. Therefore the remaining available gradient strength is utilized for the oscillating gradients. These projections in particular provide an efficient sampling for CS, leading to an improved PSF. The number, orientation and relative phase shift of the oscillations can be varied. Trajectory measurements were performed using the method proposed by Duyn [3]. In vivo cardiac data of a healthy volunteer was acquired on a 1.5T Siemens Espree scanner with a 15 channel combined spine and body array using a Moët-TrueFISP sequence with 4 oscillations per line and a golden angle reordering with a fixed number of 144 different projection angles. During acquisition, no EKG gating was used and the volunteer was advised to breathe normally. Sequence parameters were FOV=300x300mm^2, BW=830Hz/Px, TR=3.14s, FA=70. Images were reconstructed from 5, 7, 10 and 16 projections using through-time non-Cartesian GRAPPA [4]. As calibration data, 243 fully sampled frames were acquired using the same parameters with a linear reordering. Each GRAPPA kernel appears only once in every frame. Subsequently, a CS reconstruction [1] using L1- as well as total variation norm was performed on each frame after subtracting the mean image. All images were gridded using NUFFT [5] using the density compensation proposed by Bydder et al. [6].

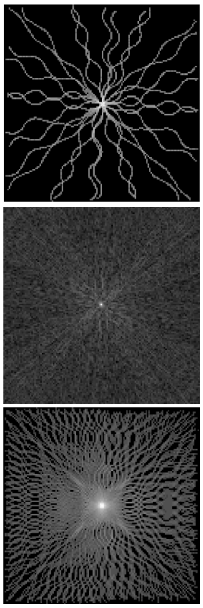

Fig 1: An example Moët trajectory. On the top are the trajectory with 16 projections and the corresponding PSF beneath, displayed on a log scale. The full trajectory (144 projections) is shown below.

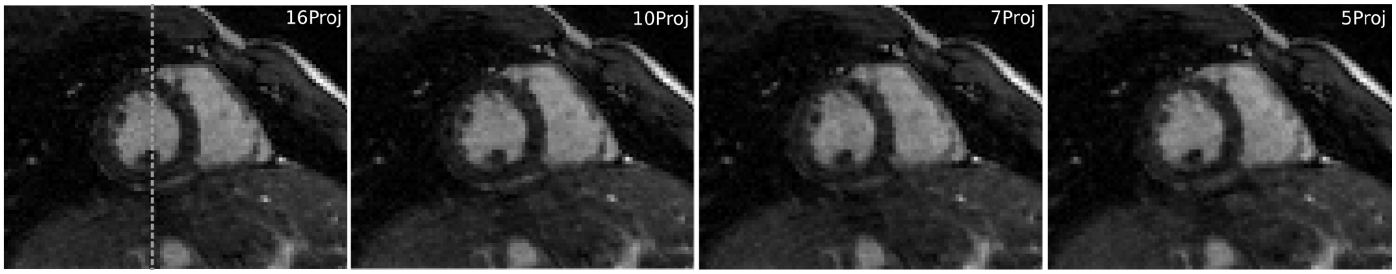

Fig 2: Reconstructed images from data obtained with Moët using a different number of projections per frame. The reconstruction was done using through-time GRAPPA and a final Compressed Sensing reconstruction.

Results: Example reconstructed images are shown in Fig. 2 for temporal resolutions of (left to right) 50.24 ms/frame, 31.4 ms/frame, 22.0ms/frame and 15.7 ms/frame. Due to the PSF of this trajectory, reconstruction errors appear as high-frequency artifacts in the temporal dimension. Thus, the image quality is maintained even for the image reconstructed using only 5 projections. An xt-image of the reconstruction using 16 projections is shown in Fig. 3.

Discussion: In this abstract we have shown the feasibility of using a non-Cartesian trajectory with an optimized PSF for Compressed Sensing and Parallel Imaging reconstructions. Moët shows promise to allow for higher acceleration factors than traditional k-space sampling methods due to the efficient 2D trajectories that are compatible with compressed sensing.

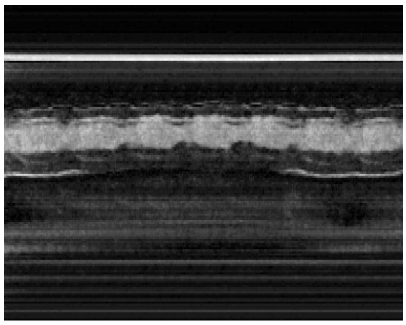

Fig 3: Visualization of the line specified in Fig. 2 in time. The motion due to free breathing is clearly visible in the temporal domain.

References: [1] Lustig M, et al. IEEE SPM 2008;27:72-82. [2] 1. F. A. Breuer et al., Magn. Reson. Med. 2008;60: 474-478. [3] Duyn, et al. JMRI. 1998;312:150-153. [4] Seiberlich N, et al. Magn. Reson Med. 2011;65:492-505 [5] http://www.eecs.umich.edu/~fessler/code/ [6] Bydder M, et al. http://dx.doi.org/10.1016/j.mri.2006.09.021

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