# k-t Sparse GROWL: A Fast and Accurate Algorithm for Highly Accelerated Dynamic Imaging

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**Introduction**

The combination of partially parallel imaging (PPI) and compressed sensing (CS) has shown great potential for highly accelerated dynamic MRI [1, 2, 3]. In this work, a self-calibrated PPI technique GROWL [4] is combined with a CS technique *k-t* FOCUSS [5] for fast and accurate reconstruction with highly accelerated data. The proposed method is called *k-t* sparse GROWL. By using golden angle radial trajectory, real time speech MRI with flexible temporal resolution can be achieved by using 16 radial projections (PRs) for each time frame. The reconstruction of a 256×16×16 data set needs fewer than 10 seconds in Matlab.

**Theory**

Radial trajectory is used as an example to explain the proposed scheme. There are two steps in *k-t* sparse GROWL for reconstruction. The first step is to use GROWL and narrow window data sharing to partially reconstruct *k*-space. Fig. 1 demonstrates the idea. For time frame *t*, GROWL operator extends original 2 PRs (black) to be 10 PRs. Red lines are the results of GROWL. The data sharing (simply copy) with immediate adjacent time frames can further increase the number of PRs to be 14 in time frame *t*. Then GROG [6] is used to shift all *k*-space data onto Cartesian grids. As shown in Fig. 1, the center *k*-space (the center black disk) only use signal from the acquired data in time *t* to preserve image contrast. GROWL operator can accurately extrapolate data to adjacent *k*-space locations [4], and does not reduce temporal resolution. Sharing of high frequency information with immediate adjacent time frame only has minimal impact on temporal resolution. The first step increases a significant amount of *k*-space data for each time frame with minimal side effects. The second step is to apply CS in *k-t* space, such as *k-t* FOCUSS, to the result of step 1 for final reconstruction. By using channel combination scheme [7], *k-t* FOCUSS is ***only applied to one combined channel*** with the largest eigenvalue. All other channels can be reconstructed using relative sensitivity maps and insertion of partially acquired data.

**Methods**

Real time speech MRI data were acquired using a 16-channel NVA coil with golden angle radial trajectory on a Philips 3T system. A gradient-echo sequence with TR/TE of 4.9/2.6 ms was used for acquisition. A total of 4096 PRs were acquired in 20 seconds when the volunteer was talking. 16 PRs were used to reconstruct each time frame. To produce the baseline images for *k-t* FOCUSS, every 512 PRs were regridding by GROG. Each baseline image was used for time frames within the time window of the 512 PRs. By sliding 8 PRs for each time frame, 25 frames/second was achieved. All methods were implemented using the Matlab programming environment, and processed on an xw4100 HP workstation with two 3.2 GHz CPUs and 2 Gb RAM. The total reconstruction time for each 256 (read out) × 16 (projections) × 16 (channels) data set was about 10 seconds.

**Results and Discussions**

Fig. 2 shows the results. When 128 PRs were used for reconstruction, the temporal resolution was low (Fig. 2a). When 16 PRs were used, the temporal resolution was improved at the cost of serious artifacts (Fig. 2b). Using the scheme shown in Fig. 1, the image quality was significantly improved (Fig. 2c). GROWL and data sharing scheme produced extra 64 and 32 PRs respectively with minimal impact on temporal resolution. This step took about 8 seconds for each time frame. After *k-t* FOCUSS, the image quality was further improved (Fig. 2d). By using the channel combination scheme, *k-t* FOCUSS was only applied to one combined channel. All other channels were reconstructed using relative sensitivity maps. Moreover, GROG was used to shift all non-Cartesian data onto Cartesian grids efficiently. Hence, this step took only 2 seconds for each time frame. Since the majority of the signals were contributed by a few combined channels with the largest eigenvalues, and the combined channels with the smaller eigenvalues either contained mainly noise [7] or had no signal contribution to the region of interest, the combination of the three channels with the largest eigenvalues was used as the final reconstruction (Fig. 2e). Fig. 2f shows the result of another time frame. Comparing Figs. 2e and 2a, it can be seen that the result of the proposed method using 16 PRs has lower aliasing artifact level than gridding using 128 PRs. In conclusion, *k-t* sparse GROWL is a fast and accurate reconstruction algorithm for dynamic imaging with high acceleration factors. Further optimization and comparison with existing techniques [1,2,3] will follow. *k-t* sparse GROWL can be directly adopted for dynamic imaging with spiral trajectory.

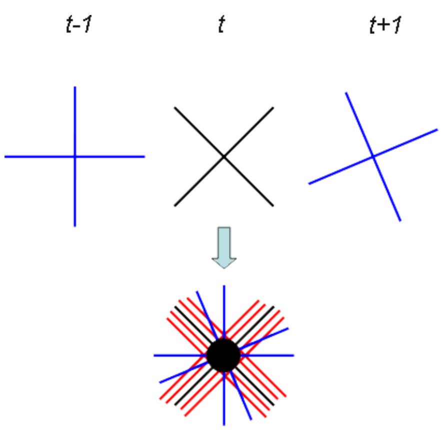


**Fig. 1.** Using GROWL and data sharing to produce initialization of *k-t* FOCUSS. The initial 2 projections become 14 projections after the procedure. Red lines are the results of GROWL.

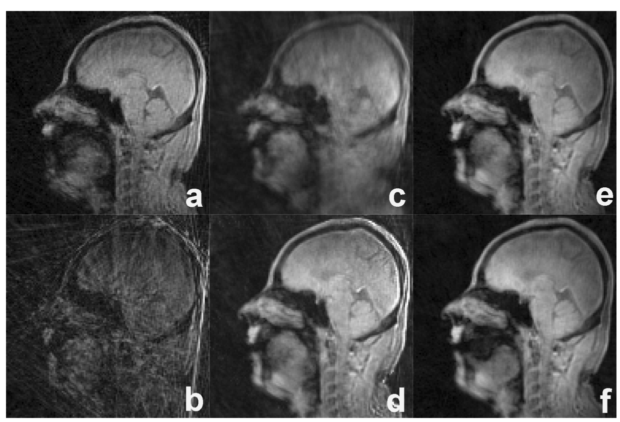


**Fig. 2**. Results of real time speech MRI using a 16-channel NVA coil. a) and b) results of gridding using 128 and 16 PRs. c) result of GROWL + data sharing using 16 PRs. d) results of the proposed method using 16 PRs .e) image using only 3 combined channels from the 16 channels for d). f) result of the proposed method at another time frame using 16 PRs and 3 combined channels

**References :**
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