Parallel Acceleration Toolkit for Image

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ng on a NVIDIA Tesla C1060 (field-corrected

and reconstruction techniques. The

MRI (IMPATIENT

results in random shifts to the

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age from a high resolution diffusion ima

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binning, data regularization

em matrix computations, and field inhomoge

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e z dimension increased by increasing the number of phase encoding

30 40.89x 1520 (est.) 83.41     N/A

C

mentation [3]. In addition, for the

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nd y directions increased by increasing

steps. All reconstructions execute 10

on includes space compaction, input

This is achieved by sorting the k-space points into bins with non-uniform capaci

ed field map approximation, the product

itrary non-Cartesian acquisitions,

d by the Toeplitz strategy enables highe

k

space trajectories are truly 3D and change for each data set.

three-dimensional data. Alternatively, gridding provides an a

rging scan reconstructing with GPU

tion, twenty-eight 240x240x32 volumes must be

ty and regular k-space coordinates.

ensure the output-driven gridding algorith

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arization (including both Tikhonov and

nals with ~65ms readouts per shot with matrix size in the x a

r resolution 3D data and more coils.

Discussion:

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Figure 1: Left: 1mm isotropic diffusion weighted image from a 3D multi-slab multi-shot acquisition reconstructed on a Tesla C1060 GPU using SENSE and field correction. Right: An FA map, with color indicating the primary direction of diffusion, resulting from 6 diffusion weighted images that took 4 hrs to reconstruct with GPU compared with one week for reconstruction on a CPU.

Figure 2: Table shows the performance comparison. Although the data would normally be amenable to gridding in-plane and a separate FFT across the slice direction, due to motion-induced phase errors in diffusion, the resulting k-space trajectories are truly 3D and change for each data set. Using a Tesla C1060 GPU, we tested three 3D datasets coming from a multi-shot stack of constant density spirals with ~65ms readsout per shot with matrix size in the x and y directions increased by increasing the number of spiral interleaves for each phase encode and the z dimension increased by increasing the number of phase encoding steps. All reconstructions execute 10 conjugate gradient iterations and 8 time segments. The ‘Time (min)’ row shows the execution timings, comparing Toeplitz-based iterative regularized SENSE reconstructions using single-precision, floating-point arithmetic with a hand-tuned, single-thread Matlab code performing the similar calculation on a CPU. In summary, we observed a speedup of more than 48x in single precision mode. A resulting example image from a high resolution diffusion imaging scan reconstructing with GPU can be seen in Figure 1. For reconstruction of a full 3D multi-slab DTI reconstruction, twenty-eight 240x240x32 volumes must be reconstructed for the whole data set. Access to nodes with multiple GPUs can provide trivial acceleration over the multiple volumes to be reconstructed.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>128x128x16 (SENSE,4coils)</th>
<th>240x240x32 (SENSE,4coils)</th>
<th>512x512x32 (SENSE,4coils)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Matlab</td>
<td>Toeplitz</td>
<td>Speedup</td>
</tr>
<tr>
<td>Time (min)</td>
<td>62.31</td>
<td>1.28</td>
<td>48.68x</td>
</tr>
</tbody>
</table>

Discussion: This paper describes the second-generation IMPATIENT MRI reconstruction toolkit. We implemented two reconstruction strategies to provide a choice of the tradeoff between accuracy and speed. Brute force, aiming for accuracy, evaluates the system matrix exhaustively without any approximations. Conversely, Toeplitz emphasizes speed more than accuracy. The large increase in reconstruction speed provided by the Toeplitz strategy enables higher resolution 3D data and more coils. These improvements will enable advances in 3D non-Cartesian sequences, such as cones and stacks of spirals, by reconstructing images in reasonable amounts of time.