INTRODUCTION Motion correction across time frames is of great importance for quantitative analysis of time-series images, such as in functional magnetic resonance imaging (fMRI). Especially with the recent development of the optogenetic functional magnetic resonance imaging (ofMRI) [1-5] technology, which enables excitation/inhibition with temporal precision leading to numerous control parameters to sort through, high-speed motion correction that can be integrated into a high-throughput system is of crucial importance to accelerate scientific discovery. To enable such process, it is critical for motion correction to be conducted in real-time while leaving sufficient time for additional computationally intense processes such as iterative reconstruction and automatic segmentation to also be integrated for real-time processing. Although many fast and accurate motion correction methods have been developed so far, further improvement in speed and accuracy is necessary for efficient ofMRI studies. Here we propose a new GPU based inverse Gauss-Newton (IGN) motion correction method, which is able to reduce the traditional computation cost from O($N^3$) to O(N) [6]. With highly optimized computations, the IGN method performs a 128×128×23 matrix size 3D fMRI registration in approximately 5.39 ms with higher accuracy than currently available methods.

RESULTS AND DISCUSSION We tested the speed, accuracy and robustness of the proposed IGN method. We compared the result with currently available methods including AFNI [7], SPM [8] and FSL [9]. In the speed test, our IGN method shows the highest speed that can complete a 3D fMRI registration in 5.39 ms in average while the second fastest method, AFNI is almost 10 times slower (AFNI 51.31 ms, SPM 383.39 ms, FSL 266.76 ms). In the accuracy test, a 120-frame fMRI phantom dataset with 10 distinct sets of known motion parameters are designed. As shown in Fig. 2, our proposed IGN method shows the lowest averaged RMS error rate 0.07 mm (AFNI 0.10 mm, SPM 0.20 mm, FSL 0.26 mm). The phantom and real ofMRI data analysis results also show that the proposed IGN method gives the highest coherence value and the largest activation volume. An example is shown in Fig. 3. As demonstrated, the proposed fast IGN motion correction method (5.39 ms) combined with the 7.41 ms parallel acquisition and reconstruction method [10] leaves ample room for additional computationally intense processes to be integrated within the acquisition TR (750ms), which marks a key step forward towards the design of high-throughput ofMRI systems.


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