Phase-Encode Ghosting Detection using Multi-Channel Coil Arrays

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INTRODUCTION:

A typical artifact in magnetic resonance imaging with Cartesian sampling is phase-encode (PE) ghosting. It is a result of spins moving between phase encoding and data sampling in an MR acquisition. This k-space inconsistency manifests as ghosting along the PE direction and bears the risk to be misinterpreted as a disease-induced tissue alteration. This detrimental effect is of particular importance in both Fluid Attenuated Inversion Recovery (FLAIR) and Rapid Acquisition with Relaxation Enhancement (RARE)-type imaging since these sequences are often employed to identify small pathological foci, e.g. multiple-sclerosis lesions. In brain images, the artefacts often appear at the posterior fossa and may significantly aggravate after a gadolinium injection due to the amplified blood signal[1].

We suggest a method to automatically detect PE ghosting in order to prevent potential misinterpretation of these artefacts by a reader as well as to provide additional information to image post-processing algorithms applied on these images.

MATERIALS & METHODS:

After obtaining written consent from three healthy volunteers, a fully sampled product 2D FLAIR sequence (TR/TI/TE 10s/2.6s/9.3ms, resolution 0.7x0.7x3mm^3, number of slices 43, slice gap 0.3mm) was acquired at 3T (MAGNETOM Skyra, Siemens Healthcare, Germany) using a commercially available 20-channel head/neck coil. . Using the k-space raw data of this scan, Generalized Autocalibrating Partially Parallel Acquisition (GRAPPA)[2] kernels where trained on the k-space center and subsequently used to calculate every k-space sample based on the weighted sum of its neighbors to generate a second k-space dataset. Afterwards, the original and GRAPPA-reconstructed k-space sets were subtracted, inverse Fourier-transformed and coil-combined using sum of squares. This yielded an image ("artifact map") containing only signal energy that violated the GRAPPA assumption, i.e. that a k-space sample is a linear combination of its neighboring samples. Amongst others, noise and PE ghosting do not correspond to this assumption and thus appear in this artifact map. In order to separate PE ghosting from noise, every outlier in the artifact map (defined as voxels >2*standard deviation of the artifact map), was labeled in a binary mask. Finally, the severity of PE ghosting per PE column was quantified by counting the number of outliers in this column[3]. Finally, the columns with detected PE ghosting were marked in the original image according to the suspected artefact severity (see Fig. 2). A flowchart of this algorithm is illustrated in Fig. 1.

RESULTS & DISCUSSION:

A slice of the posterior fossa is shown in Fig. 2. Zooming into the cerebellum reveals a ghosting artifact caused by blood flow pulsation of the posterior inferior cerebellar artery, which may be misinterpreted as an MS lesion. The algorithm successfully detected these image columns as affected by PE ghosting, which is indicated by the red severity-scaled overlay bars. Additional artifacts at the brainstem caused by the vertebral arteries were as well detected.

In current clinical routine, the acquisition of FLAIR images is usually accelerated using parallel imaging techniques. In that case, the k-space does not meet the requirement of being fully sampled anymore. However, the PE-ghosting detection could be applied after a standard GRAPPA reconstruction. Simulations indicate, however, that the sensitivity of the algorithm will be reduced because the ghosting will be more spread in the artifact map and may not exceed the outlier cut-off level.

CONCLUSION:

The presented technique uses GRAPPA to create a duplicate of an acquired k-space. The original and the duplicate image differ where the assumption that the k-space data point is a linear combination of its neighbors is violated. Obtained difference maps reveal corresponding artifacts, e.g. spatial locations where PE ghosting artefacts occur and may provide an indication about their expected severity. This may help to avoid misinterpretation of artifacts as disease effects by providing additional information to the radiological reader or to automated post-processing algorithms such as morphometric analysis or lesion detection techniques.

REFERENCES:

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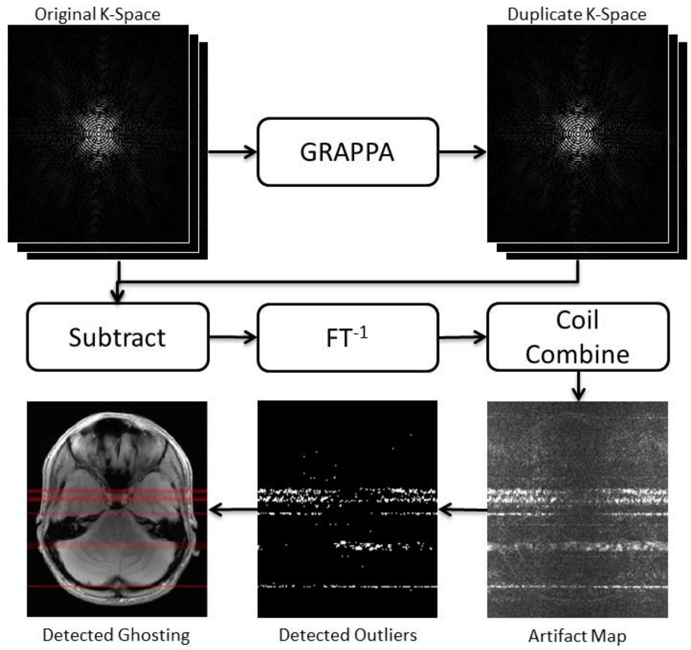

Fig. 1: *In order to detect phase-encode ghosting, the original k-space is first duplicated using GRAPPA. Subsequently, the difference of the two k-spaces is transformed into image domain and used to quantify the severity of ghosting.*

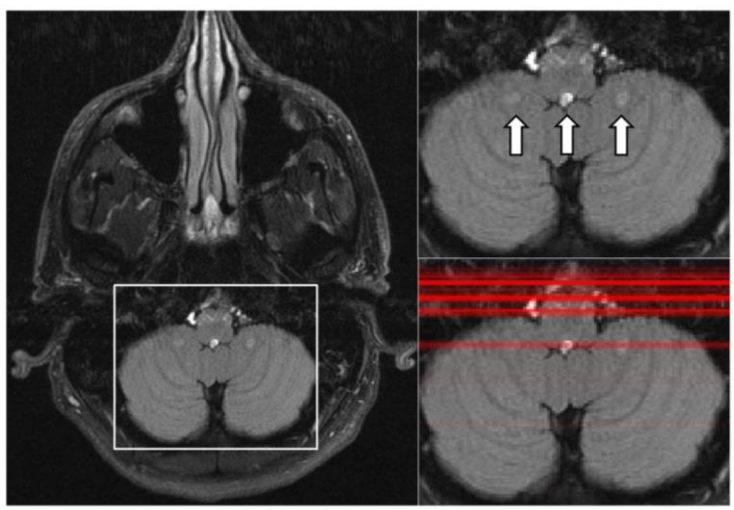

Fig. 2: *A FLAIR image of the posterior fossa (left) and a zoom into the cerebellum (top right) with PE ghosting artifacts of the posterior inferior cerebellar artery (arrows) which were detected and indicated as artifactual by the proposed algorithm (bottom right).*

Synopsis: Phase-encode ghosting artifacts frequently occur in magnetic resonance imaging, especially in spin-echo sequence derivatives such as fluid-attenuated inversion recovery. The appearance of these artefacts may cause misinterpretation as tissue pathology, e.g. a lesion. We propose an algorithm to automatically detect these artifacts by analyzing the consistency of the acquired k-space with respect to the assumption of GRAPPA that a k-space sample is a linear sum of its neighboring samples. The performance of the technique is shown in three volunteers. It may help to avoid potential misinterpretation in the future, both for radiological readers and automated post-processing algorithms.