

Automated detection, evaluation and removal of DWI-related artifacts

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Introduction

In the last two decades, Diffusion-Weighted Imaging (DWI) has been widely employed for the evaluation of invariant index maps based on Diffusion Tensor Imaging (DTI) [1] and for the white matter fiber tractography based on the more recent High Angular Resolution Diffusion Imaging (HARDI) [2]. For this reason, the evaluation of DW image quality becomes fundamental in the typical DWI pre-processing flowchart. Several works in the literature examined in detail the different types of artifacts that can affect the DW images and investigated the several possible sources [3]. Pitfalls in DWI analysis [4] and classification of artifacts have been studied [5] along with strategies aimed to reducing their negative effects [6-7]. Here we present a tool for the automatic detection of isolated artifacts that may affect any slice of the imaged volume at one or more gradient directions, allowing for qualitative and quantitative image quality evaluation and subsequent artifact removal and correction of the corresponding diffusion gradient table for proper reconstruction.

Methods

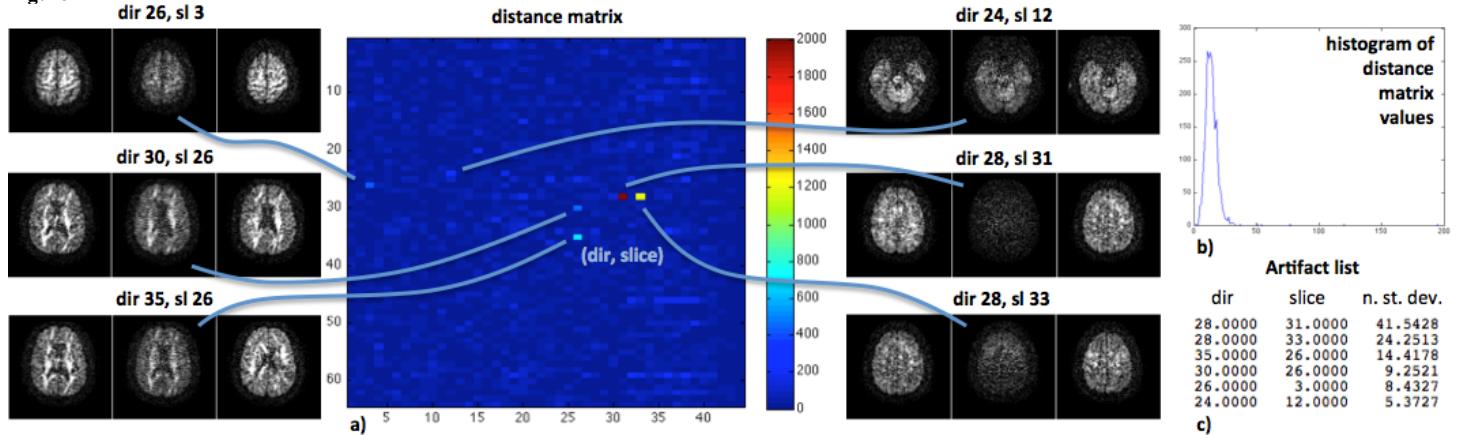
Detection step: for each image of the 4D DWI volume a histogram of the corresponding gray value occurrences is generated (Figures 1.a and 1.b). For each slice, a median histogram is obtained (Figure 1.c) by computing the median of the histograms along the different directions. Then, for each histogram, the value-to-value difference with respect to the corresponding median histogram is computed. A consequent distance matrix is obtained (Figure 2.a) and a histogram of its values is generated (Figure 2.b). Then, the mean and the standard deviation are computed by performing a Gaussian fit. For each value of the distance matrix, finally, the distance from the mean value in term of standard deviations is computed.

Evaluation step: distances of each value of distance matrix from the mean in term of standard deviations can be used to identify potential artifacts. This step can be performed in a fully automatic way by blindly setting a threshold in term of standard deviations and obtaining a list of detected artifact (Figure 2.c) or, alternatively, in a semi-automatic way by visually evaluating the image quality of the slice corresponding to the (dir, slice) coordinates of the suspected value in the distance matrix.

Removal step: for each artifact detected, the tool proceeds to remove the entire volume corresponding to the affected direction. Subsequent rearrangement of the coordinate table of the diffusion gradients is performed by deleting the corresponding line.

The described data analysis was tested on 4D DWI volumes acquired with a 1.5T GE Signa Horizon magnetic resonance scanner. The software tool was created by using the Matlab programming language.

Figure 2



Results

The distance matrix shows a predominance of low values with a few isolated brighter spots. These spots reveal the presence of images whose histogram shape is sensibly dissimilar to the shape of the corresponding median histogram. The first two columns of the artifact list report the coordinates of the detected artifacts, whilst the third column quantifies the entity of the disruption in term of standard deviations. For each line of the artifact list it is possible to visually verify the presence of an artifact by comparing it to the two adjacent slices corresponding to other directions of the diffusion gradients. A new 4D DWI volume is generated by removing the volume corresponding to the affected direction and a new coordinate table of diffusion direction is created, allowing the user to start the subsequent DWI analysis.

Conclusion

In conclusion, the proposed algorithm for the automatic detection and removal of diffusion-related artifacts seems to be a useful tool to be exploited in the normal DW images pre-processing. It allows the user to detect and evaluate potential artifacts and, if required, to remove the volume corresponding to the detected artifact and rearrange the coordinate table of the applied diffusion gradients.

References: [1] Le Bihan NMR in Biomedicine (2002) 15:7-8, 431-434. [2] Tuch DS Magn Reson Med (2002) 48:4, 577-82. [3] Robson Magn Reson Imaging (2005) 23:9, 899-905. [4] Jones DK NMR Biomed (2010) 23:7, 803-820. [5] Le Bihan D J Magn Reson Imaging (2006) 24:3, 478-88. [6] Winter JD Magn Reson Imaging (2007) 25:9, 1283-1291. [7] Gallichan Hum Brain Mapp (2010) 31:2, 193-202.