Dynamic correction of geometric distortions in high-resolution functional MRI at ultra-high magnetic field strengths

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In neuroscience research, the use of functional magnetic resonance imaging (fMRI) at ultra-high ($\geq$7T) magnetic field strengths improves significantly the signal-to-noise ratio (SNR). However, fast imaging techniques like Echo-Planar Imaging (EPI) are prone to geometric distortions due to local field inhomogeneities, which become more pronounced at higher field strengths and can cause the mislocalization of relevant signal. To mitigate those distortions, conventional static correction methods use one snapshot fieldmap applied to all fMRI magnitude images. Other dynamic methods compute one fieldmap for each EPI time point from preliminary Gradient echo (GRE) images. By doing so, it accounts for the changes in the static magnetic field occurring during the acquisition time, including motion or breathing.

In this thesis, a new dynamic geometric distortion correction method is presented and compared to existing corrections. The technique uses a fieldmap computed from EPI images acquired with opposite phase encoding (PE) directions. This reference fieldmap is then used to estimate the constant phase offset present in all EPI phase data. A series of dynamic fieldmaps can thus be calculated from the EPI phase, and each volume is corrected independently. The main advantage of this method is to allow for a dynamic correction without the need for preliminary scans.

To perform a complete analysis of the methods, six different correction pipelines have been implemented. Two of them use a static fieldmap computed from GRE preliminary scans, with and without extra modelling of the susceptibility-by-motion effect. Two others compute a fieldmap from EPI volumes acquired with opposite PE direction, then apply it with and without the same extra model as before. Finally, two dynamic corrections have been implemented, estimating the phase offset based on preliminary GRE or on reversed PE acquisition. These methods have been tested on different datasets acquired at 7T at University College London, including one chin approach task inducing dynamic changes in the static field. The results showed that for 3D EPI and small motion (<1mm translation and <1° rotation), using a static correction without extra modelling lead to a slightly better temporal stability. The dynamic corrections seem to induce extra variance, due to the extra computation steps present in the methods. However, to observe significant differences between the methods, the sequence and the task should be chosen wisely.

Future studies should focus on assessing the temporal behaviour of the different correction methods in a non-accelerated 2D unsegmented EPI sequence with greater head motion and a chin approach task. This would allow determining if this newly developed method visibly improves the temporal stability along the volumes.