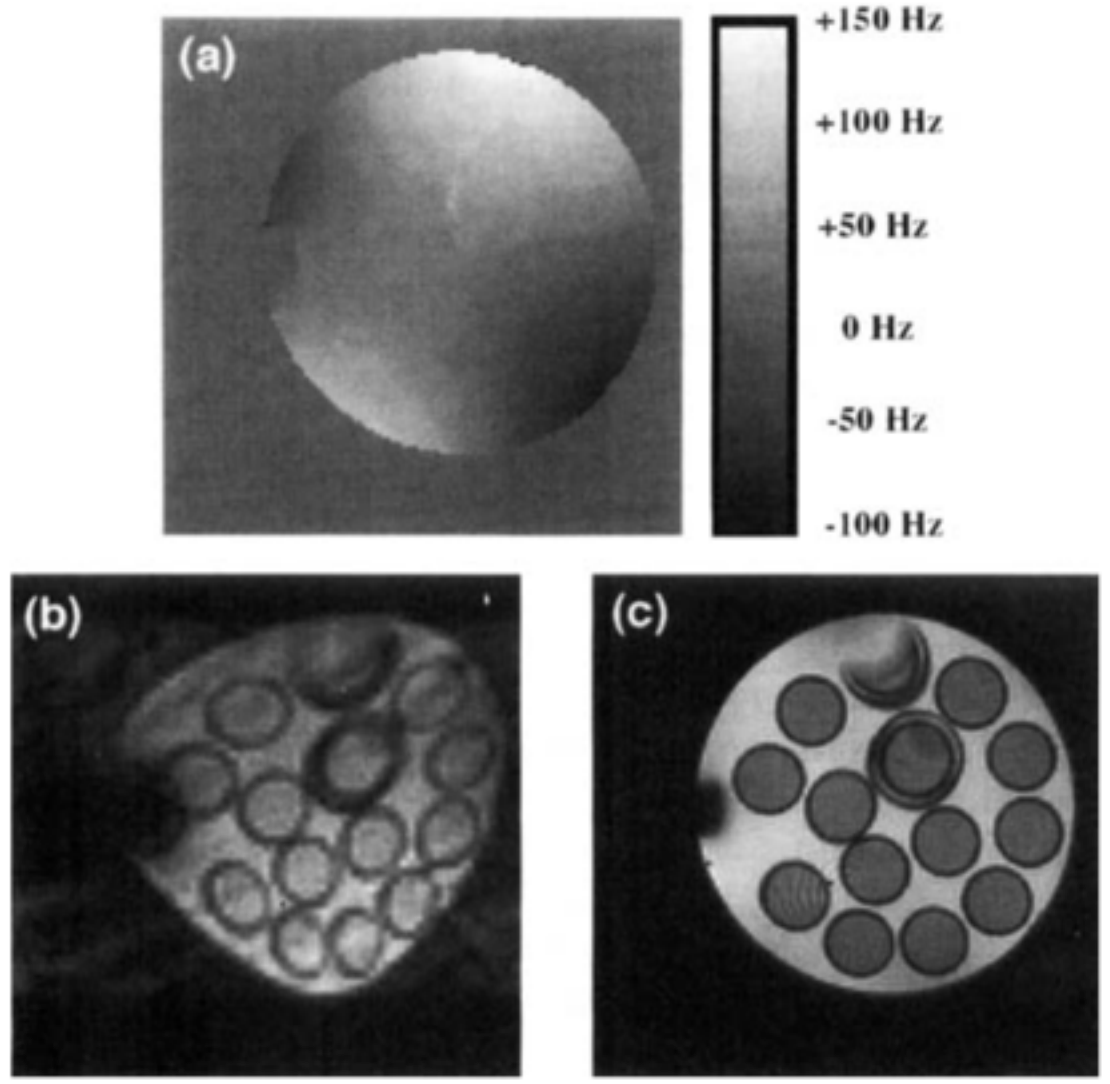
FIELD MAPS

- Calculate a field map based on the difference in phase between two different echos in a double echo sequence



Correction for Geometric Distortion in Echo Planar Images from B_0 Field Variations

Peter Jezzard, Robert S. Balaban

A method is described for the correction of geometric distortions occurring in echo planar images. The geometric distortions are caused in large part by static magnetic field inhomogeneities, leading to pixel shifts, particularly in the phase encode direction. By characterizing the field inhomogeneities from a field map, the image can be unwarped so that accurate alignment to conventionally collected images can be made. The algorithm to perform the unwarping is described, and results from echo planar images collected at 1.5 and 4 Tesla are shown.

Key words: echo planar imaging, EPI; geometric distortion; field map correction.

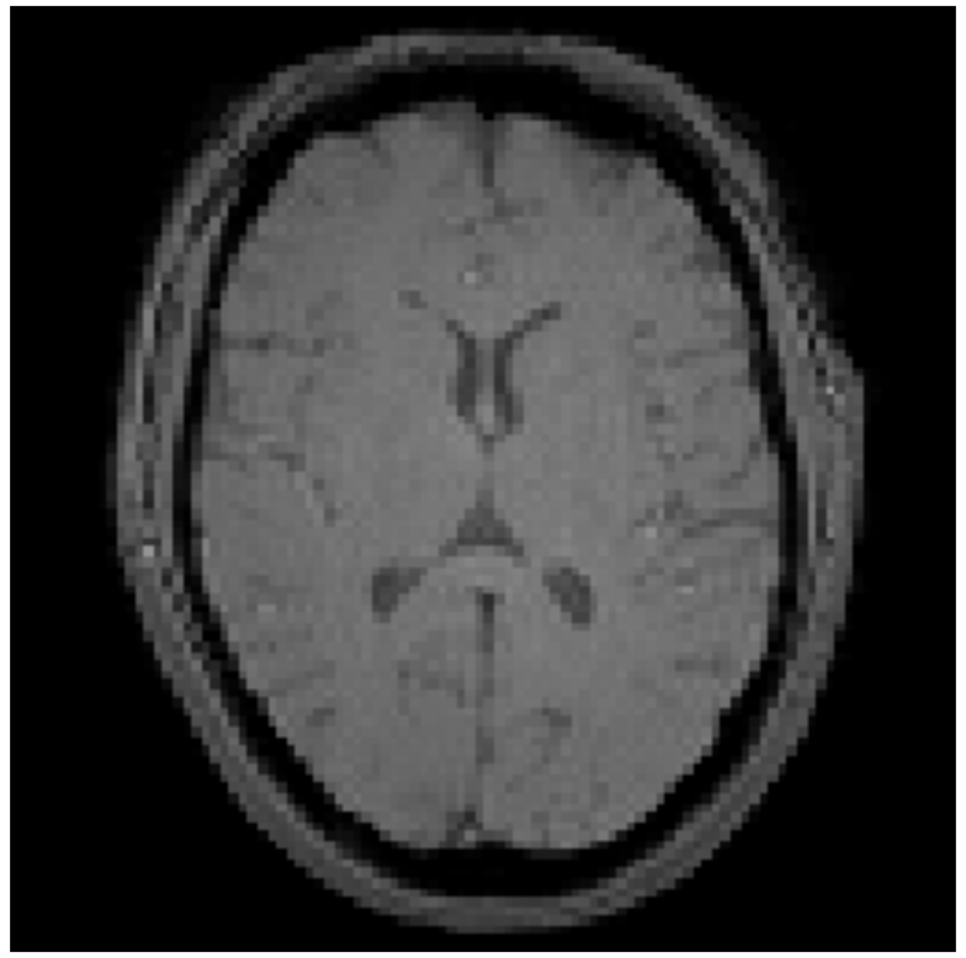
INTRODUCTION

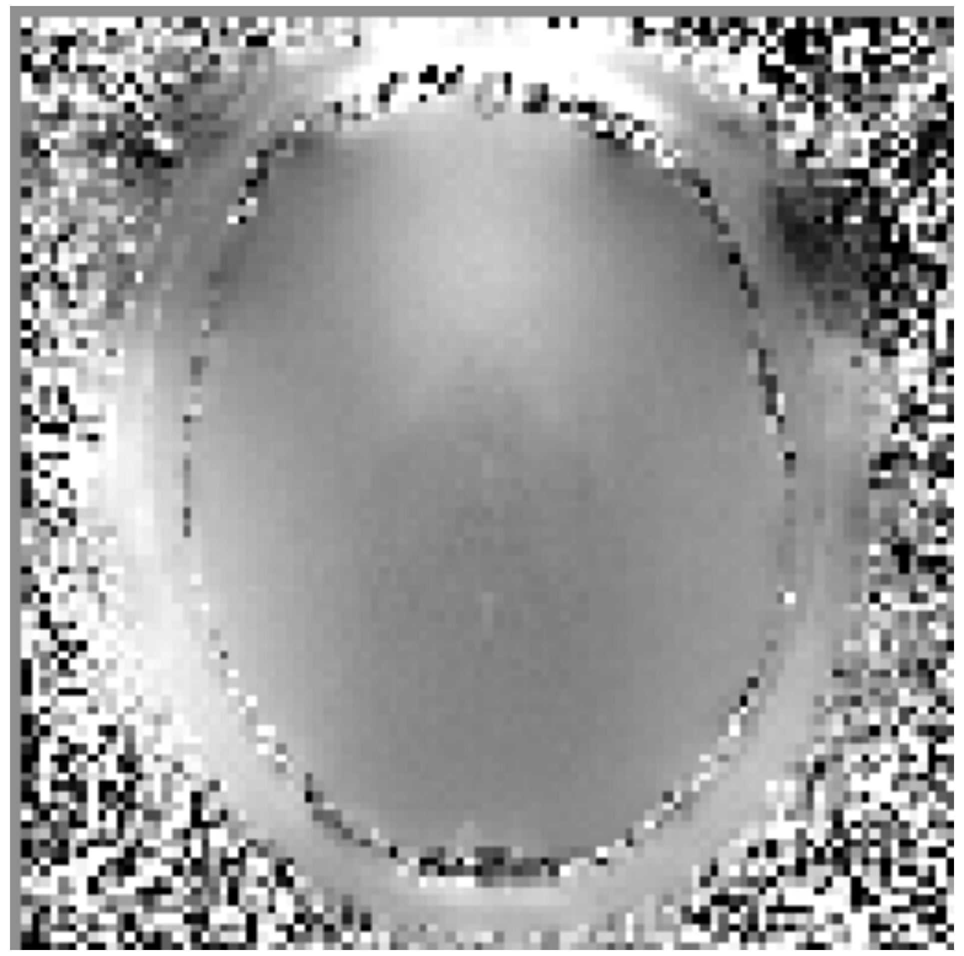
Echo planar imaging (EPI) was conceived and developed by Mansfield's group in Nottingham (1, 2) and further developed by others (3). Initially a little used sequence,

rior frontal regions. The magnetic field inhomogeneities cause pixels in the echo planar image to be shifted from where they should appear, and if the inhomogeneities are sufficiently bad, gross image distortion results. If the magnetic field inhomogeneities can be characterized by means of a residual field map throughout the volume of interest, then the distorted pixels can be relocated and intensity corrected to give a geometric distortion-free image. Accurate registration with high resolution anatomical images can then be made.

THEORY

The phase evolution of a pixel in a magnetic resonance image is dictated by the local magnetic field that it experiences. In general, for an elemental point in a volume of interest, the signal induced in the NMR receiver coil is





$$\Delta B_0(x, y, z) = (2\pi\gamma\Delta TE)^{-1}\Delta\phi(x, y, z).$$

Jezzard et. al. 1995

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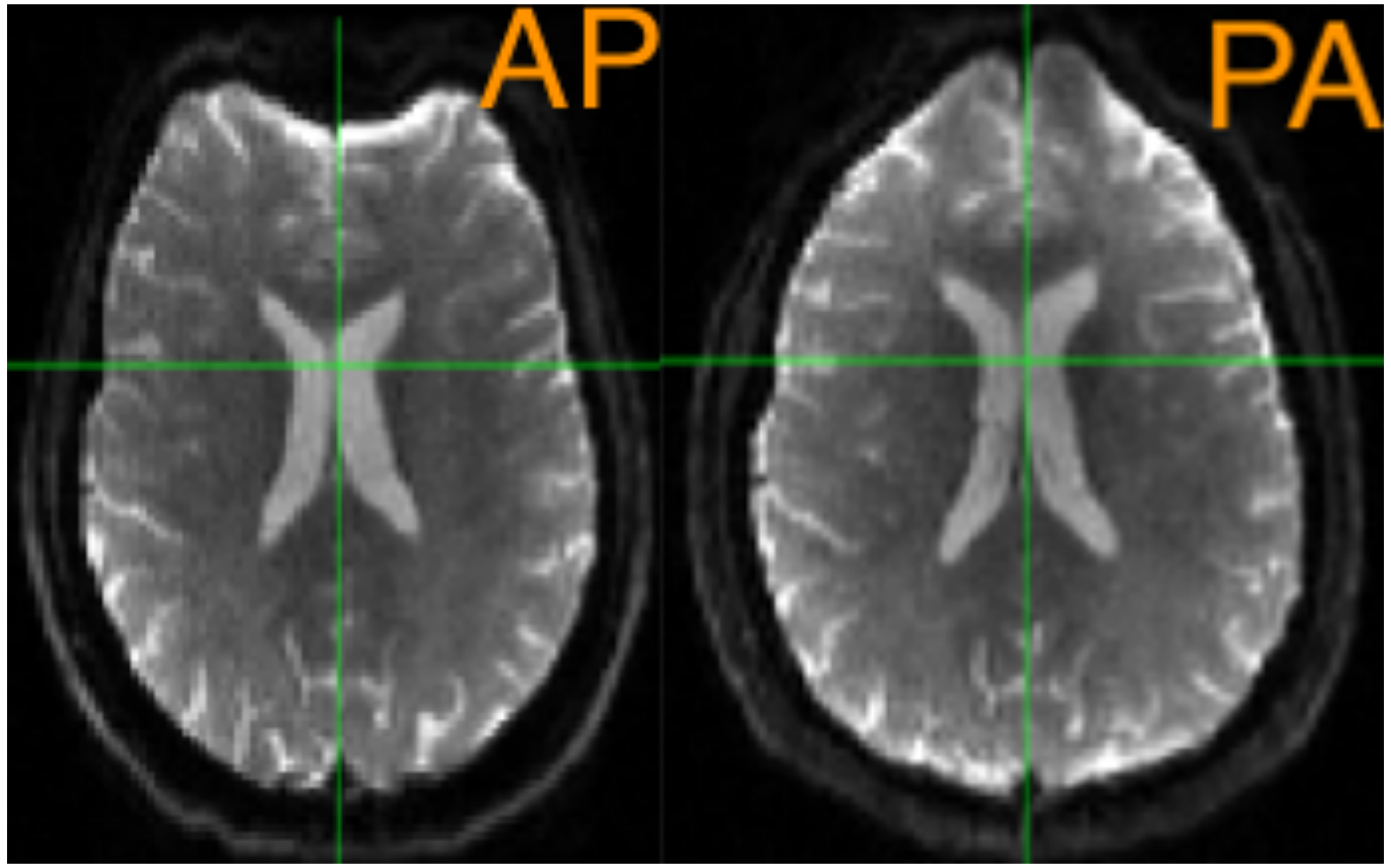

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How to correct susceptibility distortions in spin-echo echo-planar images: application to diffusion tensor imaging

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Abstract

Diffusion tensor imaging is often performed by acquiring a series of diffusion-weighted spin-echo echo-planar images with different direction diffusion gradients. A problem of echo-planar images is the geometrical distortions that obtain near junctions between tissues of differing magnetic susceptibility. This results in distorted diffusion-tensor maps. To resolve this we suggest acquiring two images for each diffusion gradient; one with bottom-up and one with top-down traversal of *k*-space in the phase-encode direction. This achieves the simultaneous goals of providing information on the underlying displacement field and intensity maps with adequate spatial sampling density even in distorted areas. The resulting DT maps exhibit considerably higher geometric fidelity, as assessed by comparison to an image volume acquired using a conventional 3D MR technique.

Introduction

A number of techniques to assess differences in gross anatomy between healthy and diseased subjects based on neuroimaging have recently been proposed (e.g., Ashburner et al., 1998; Ashburner and Friston, 2000, Good et al., 2001) and applied (e.g., Wright et al., 1995; Gaser et al., 1999; May et al., 1999; Maguire et al., 2000). An interesting addition to this arsenal is represented by diffusion tensor imaging (DTI) (Le Bihan et al., 1986; Turner et al., 1990; Basser et al., 1994; Pierpaoli et al., 1996), which may potentially offer information on differences in the hardwiring of corticocortical connections between different groups.

While alternative methods exist (e.g., Gudbjartsson et al., 1996) most DTI is based on spin-echo echo-planar images (EPI) acquired with and without special diffusion

diffusability of water. A well-known problem with EPI is the geometrical and intensity distortions caused by field imperfections in conjunction with the poor bandwidth in the phase-encode direction. These field imperfections are caused by, among other things, eddy-current-induced global gradients (Jezzard et al., 1998) and susceptibility induced local gradients (Jezzard and Balaban, 1995). We have in previous work dealt with the first of these (Andersson and Skare, 2002) and in the present paper we will address the latter.

We further an idea proposed by Bowtell et al. (1994) which entails collecting two echo-planar images, once traversing *k*-space bottom-up and once top-down. This results in two images with identical magnitude distortions in opposing directions. These two images, together with a model for the image formation process of spin-echo EPI, allow us