Stereoscopic Acquisition and Display of MR Spectroscopic Images

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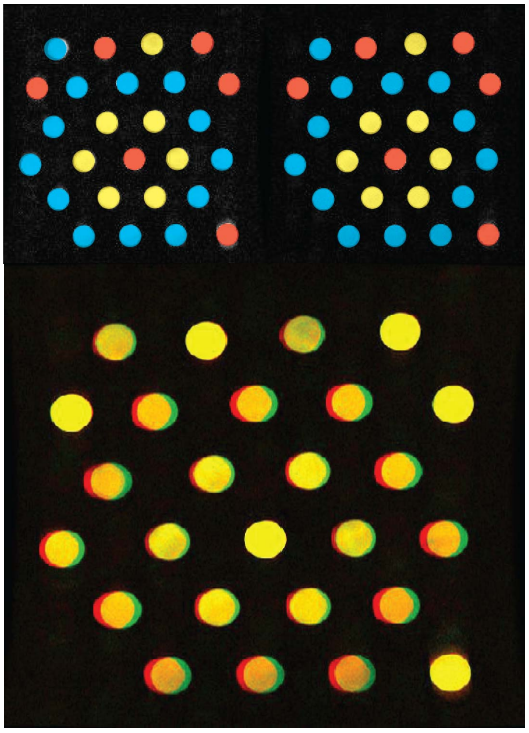
Introduction

The flexibility of MR imaging is emphasised when new methods for encoding information into images (such as directional diffusion weighting, in the case of DTI) can be combined with appropriate display method (such as RGB colouring to denote fibre orientation[1]). In this abstract, we present a novel and efficient method for encoding chemical shift as depth information in stereoscopic MR images, through combining two images acquired with different bandwidths to harness the chemical shift displacement in the frequency-encoding direction for depth encoding. Previous stereoscopic MRI[2] work has focused on encoding literal depth information into images, rather than encoding additional information in that dimension.

Theory

A basic problem for the human visual system is the reconstruction of a 3D world from the 2D projection arriving at the photoreceptors of the retina. As noted by Leonardo da Vinci[3], even though monocular cues to depth such as occlusion and perspective are preserved, the projection process to a single image necessarily involves the loss of some depth information: "a painting, though conducted with the greatest art …can never show a *relievo* equal to that of the natural objects".



Crucially, the brain also takes advantage of the fact that the two eyes see the world from slightly different viewpoints. By comparing the relative 2D position of objects on the two retinas the brain is able to recover depth in the scene. Using similar techniques, stereoscopic projection methods (e.g. presenting stereo pairs side-by-side for cross-fusion or overlaying them for viewing with red-green glasses) allow different information to be presented to each eye and give rise to compelling 3D images. True stereoscopic imaging requires two images obtained from different viewpoints, however, in the absence of oblique surfaces, this can be approximated by encoding depth as a differential left-right shift. The chemical shift 'artifact' in MRI appears as a relative displacement in the frequency-encoding direction of signals arising from spins with a different resonant frequency. Thus chemical shift information can be encoded using the depth dimension by acquiring paired images with different imaging bandwidths, and presenting them one to each eye.

Methods

A multi-compartment phantom of 26 vials (25 mm o.d.) containing water (red in diagram left), methanol (yellow) and acetone (blue below) was prepared (chemical shifts: 4.7 ppm; 3.4 ppm; 2.0 ppm). Fast spin echo MR images were acquired on a 3 Tesla GE HDx Signa scanner, using the body coil for transmit and receive. Images with bandwidths of 30 kHz and 10 kHz (across a 30 cm FOV) were acquired, displayed in red and green, and overlaid. Other parameters: TE 30 ms; TR 1260 ms; echo train 24; acquisition matrix: 512x256; slice thickness 6 mm; experiment time: 18s. Transverse fast gradient echo images of the leg were acquired with the following parameters:. Transverse fast gradient echo images of the torso were acquired with bandwidths 31 kHz and 8 kHz; TE 4.3 ms; TR 25 ms; flip angle 40; slice thickness 5 mm; 3 averages.

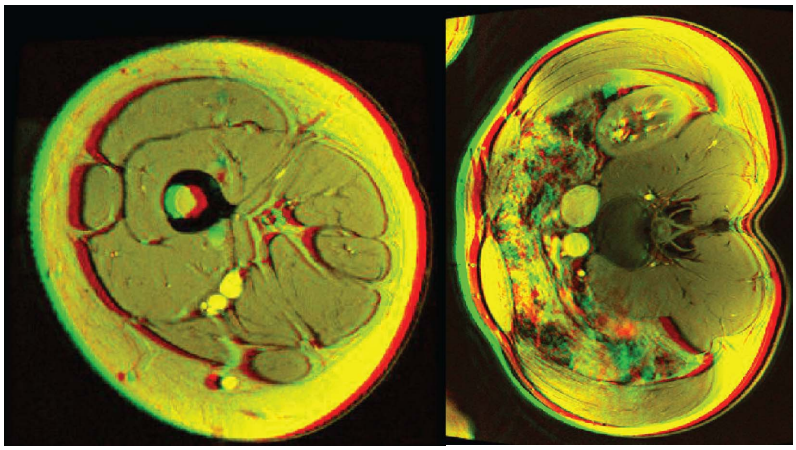
Results

In the panel upper left, the acquired phantom images are displayed side-by-side (false colour added to denote compounds) and can be merged for 3D viewing. The image lower left is a superposition of the two bandwidth images red- or green-filtered for viewing with 3D glasses (ideal distance ~ 30 cm). Chemical shift is encoded in the depth dimension, and the different planes can clearly be resolved. In the body images below, water- and fat-containing tissues can be differentiated on the basis of depth.

Discussion

This method represents an exceptionally economical method of chemical shift encoding, using just 2 encoding steps (the two bandwidths) and borrowing resolution from the left-right dimension. This method has wider applicable for encoding information into a third dimension e.g. MR flow encoding or in high-resolution NMR spectroscopy (which has the advantage of sparse information content) for efficient encoding of a 3rd dimension.

An additional consideration is the appropriate signal intensity in a pixel where signals of different chemical shift and spatial origin become coincident in the image. From real-world visual experience (which we are emulating to recreate depth separation), the image value would be expected to be that of the front object (if it is opaque) or otherwise intermediate between that of the two objects. In an MR image, the pixel intensity will be the modulus of the vector sum of the two coincident values, which is likely to be greater than either value (in contrast to the visual case). For two signals with modulus a and b, the modulus of the vector sum is $(a^2+b^2-2ab\cos\theta)^{½}$, and in order to limit this to values between a and b, θ must lie between $\cos^{-1}(a/2b)$ and $\cos^{-1}(b/2a)$. The relative phase of signals with different chemical shifts can be set by altering the echo time; however through T_2^* relaxation the intensities of the two signals will also vary with echo time. Thus, it was simplest to determine an appropriate echo time empirically.



References: 1. Pajevic and Pierpaoli MRM 42 (1999) 526. 2. Guttman and McVeigh, MRM 46 (2001) 317. 3. Da Vinci L, Trattato della Pittura.

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