

Three-Dimensional Phase Unwrap: B0 Brain Maps at 3T

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Introduction

There has been a large effort in unwrapping 2D phase images (1). 3D phase unwrapping is needed for MRI applications such as B0 mapping and improving image quality (2 - 5). A new automatic fast, three-dimensional unwrap algorithm eliminates phase jumps.

Method

A 3D phase unwrap algorithm was developed for 3D MR phase imaging. The third dimension provides a means to avoid defects that otherwise would give artifacts. Point defects (1) in two dimensions, "poles", are line defects in three dimensions, "dislocations". Image processing unwraps the high quality phase data before reaching the ambiguous defect voxels: 1) Select a seed location in region of interest; 2) mark the seed location; 3) find the locations of candidate unmarked adjacent voxels; 4) mark the candidate location and calculate the phase difference $d\phi$ with respect to the seed voxel; 5) Unwrap each candidate voxel phase ϕ ; test each candidate [a) if $d\phi > \pi$, $d\phi = \phi - 2\pi$; b) if $d\phi < -\pi$, $d\phi = \phi + 2\pi$]; 6) sort all the candidates in ascending order according to the absolute phase difference, $|d\phi|$; 7) use the smallest candidate $|d\phi|$ to seed the next iteration; 8) Repeat 3-7 until all the voxels are marked and unwrapped. Phase difference head image of consenting healthy volunteers were acquired at 3T. Two 3D complex image data sets were acquired with 3D SPGR sequence. In the first 3D set, 128 coronal images 1.5mm thick were acquired ($\Delta TE=6$, $TR=21$, $flip=15$, 256×256). A second set of 160 axial images 2mm thick was acquired to estimate the magnetic field variation brain segmented using the bubble wave algorithm ($\Delta TE=5$, $TR=25$).

Results

Two sets of 3D phase difference images were acquired at 3T. Images are shown before and the unwrapping algorithm removed the phase jumps, Fig.1. Calculating the phase difference of 160 images with 256×256 resolution took 3 seconds (53 images per second) while this 3D phase unwrapping program took 20 seconds (8 images per second). The images were processed with a 2 GHz, Pentium 4 computer with 750 MBytes of memory. The unwrapped phase images were reformatted to provide a head 3D B0 map.

Summary

A fast, robust three-dimensional phase unwrapping algorithm provides a B0 map of the head at 3T.

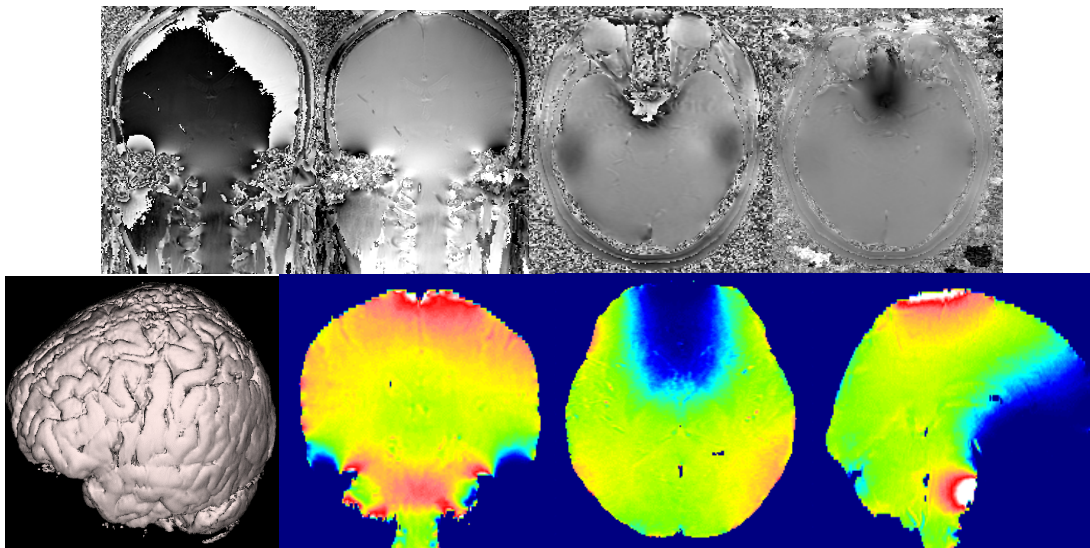


Figure 1. A coronal and axial 3D data set were unwrapped, top row . A brain volume of the coronal data set was segmented (6) and the corresponding B0 map constructed using a 1.6 ppm range.rainbow color palette.

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