HW10: Answer Key

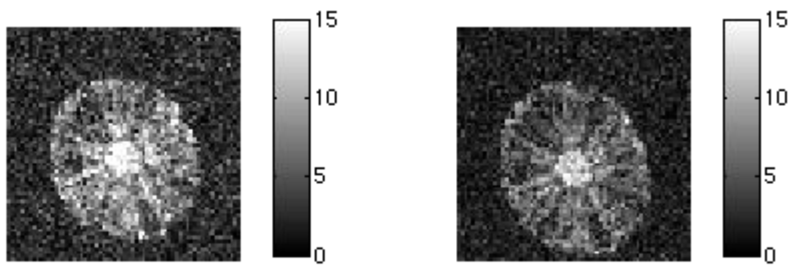
Problem 1A: thermal noise. Look at the background voxels -- displayed with the same color scale, the salt-and-pepper noise in the background is larger in the image on the left than in the image on the right. Why?

Higher bandwidth for the acquisition shown on the left resulted in a lower thermal SNR.

Problem 1B: distortion. Why is the 2nd pineapple slice more distorted than the first?

Lower bandwidth for the image on the right resulted in a longer total read-out time, creating more severe distortions.

Problem 1C: the real world. We simulated an EPI acquisition with the same echo time for both images. The thermal noise decreased when we decreased bandwidth, like it was supposed to, and the distortion increased, like it was supposed to. But there's more going on with that 2nd image than just distortion ... the signal inside the pineapple is more degraded. Why? (No right answer ...)



Even though the echo times are the same, the long read-out time for the image on the right may mean that the signal has almost completely decayed by the time we get around to reading out the high spatial frequency information (top edge of k-space, the way we usually illustrate it). It's also possible that the increased distortion creates an effectively larger T2* by mixing signals that are experiencing different local field strengths.

Problem 2: Using distortion compensation

2A: a list of all the files created, with description of the information in each file and what it's used for.

mag_stripped.nii.gz: a skull-stripped version of the magnitude data from the fieldmap. Not actually used.
(Note that mag.nii actually is 2 volumes; you can see the different contrasts resulting from different echo times.)

mag_stripped_mask.nii.gz: a binary mask for the stripped mag data (the file actually used later to mask the phase map before running PRELUDE or following steps.

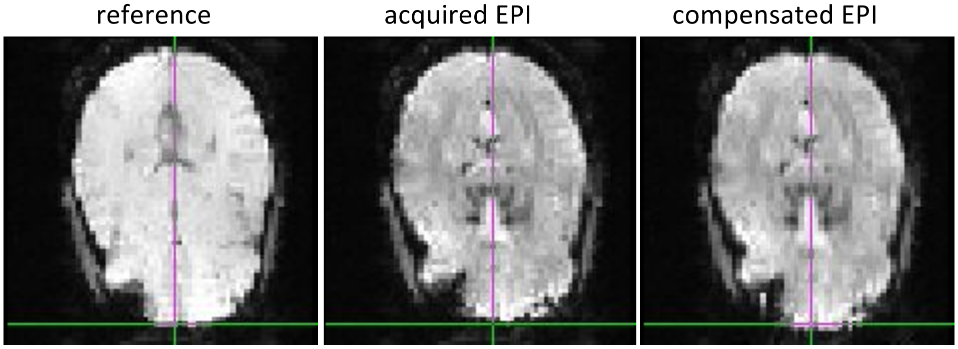
ph_rad.nii.gz: the phase portion of the fieldmap, converted from arbitrary units that came off the scanner (0-4095) to radians. This file is an intermediate step in calculating the field map.
(First we subtracted 2048, since FSL expects the phase map to have values between –pi and pi, then we multiplied by pi and divided by 2048.)

ph_rad_unwrapped.nii.gz: the unwrapped phase map, another intermediate step.
(Unwrapping is required because in locations of very high field perturbation, phases evolve more than 2pi radians during the 2.46 ms difference in echo times.)

ph_rad_per_ms.nii.gz: the field map, in radians per milliseconds. This is used to unwarp the EPI data.
(FSL wants fieldmaps in radians/time instead of Hz. We could calculate a field map in rad/s, but then we would have to supply a echo-spacing … what FSL calls dwell time … in seconds. Working in rad/ms minimizes the number of 0s we have to type.)

epi_unwarped.nii.gz: the unwarped EPI data, the final product.
(To do the unwarping, in addition to having a field map, you needed to know (1) the echo-spacing (total read-out time), (2) the delta-echo time for the field map, and (3) the phase encode direction.)

reference acquired EPI compensated EPI



This particular axial slice shows that, in the acquired EPI data (middle image) frontal cortex tissue was pulled in a posterior direction (the green line is right at the front of the brain in the reference image from the magnitude part of the fieldmap data on the left, but is in front of the brain in the middle image). The distortion compensation was, however, a little over-zealous in compensating for this, bringing the tissue a little too far forward (past the green fiducial line). In general, the unwarped brain is more brain-shaped, but in the details, the distortion compensation (1) creates blurring, and (2) is not always accurate (over- or under-compensates).