Phantom Correction of Human Images for Spatial Scaling Errors

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Introduction Previous work [1] has demonstrated the ability of the Alzheimer's Disease Neuroimaging Initiative (ADNI) phantom to measure and track scanner performance. The ADNI phantom is a water-filled phantom with 165 inclusions containing copper sulfate solution. One 6.0 cm diameter inclusion is used to estimate SNR, four 3.0 cm diameter inclusions with varying molarity solutions are used to estimate contrast properties, and 160 small (1.0cm and 1.5cm diameter) spheres are used to assess geometric fidelity. In this abstract, we evaluate the feasibility of correcting for scaling errors caused by discontinuity or drift in gradient calibration within a single system. We also investigate correction for difference in gradient calibration across field strength and systems.

Materials and Methods ADNI is a longitudinal study of aging and dementia involving approximately 820 human subjects each of whom is scanned multiple times over 2-3 years. Subjects are enrolled at 58 different clinical sites, and scanned on 84 different scanners (57 1.5T, 27 3T). The primary structural MRI sequence is an MP-RAGE with nominal TI/TR/TE/flip of 1000/2400/minimum full ~5 ms/8^{o} at 1.5T. Each enrollment site has a copy of the ADNI phantom and each human exam is followed immediately by a phantom exam. Comparing observed fiducial marker locations to design locations, estimates of voxel size mis-calibration are obtained and the associated human image voxel sizes can be adjusted.

In order to assess the efficacy of phantom-based voxel size adjustments (VSA), we performed intra-subject co-registration of 671 ADNI image pairs using AIR 5.0 [2] with image driven thresholding and a mask to restrict the registration cost function to the head excluding the neck. From a 9DOF registration, translation, rotation and relative scaling between the images was determined. Intra-subject pairs of images are compared with and without phantom-based VSA. That is, one registration was done on un-scaled images, and one after VSA. We then assessed whether VSA reduced the observed deviation of intra-subject registration scalings.

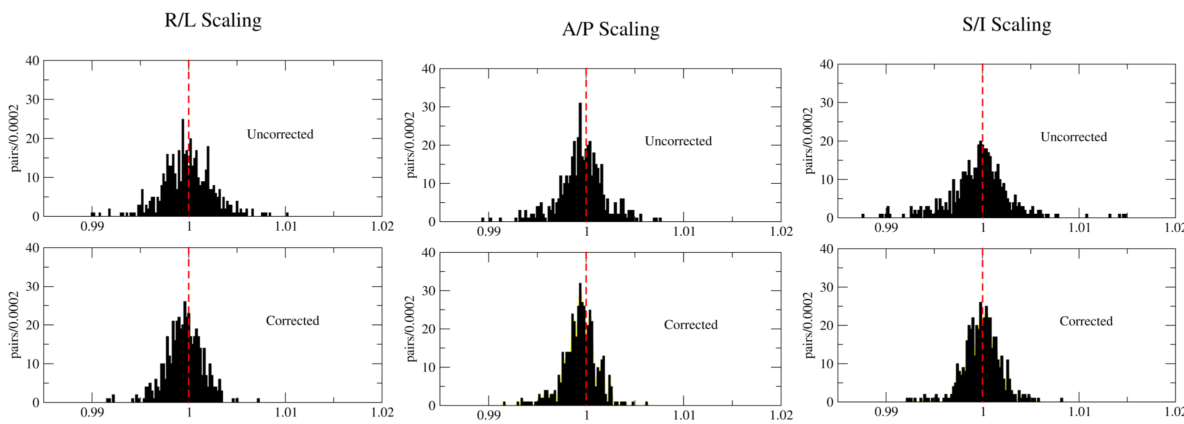

Figure 1 Scale factors in each cardinal direction from 465 pairs of human subjects at 1.5T

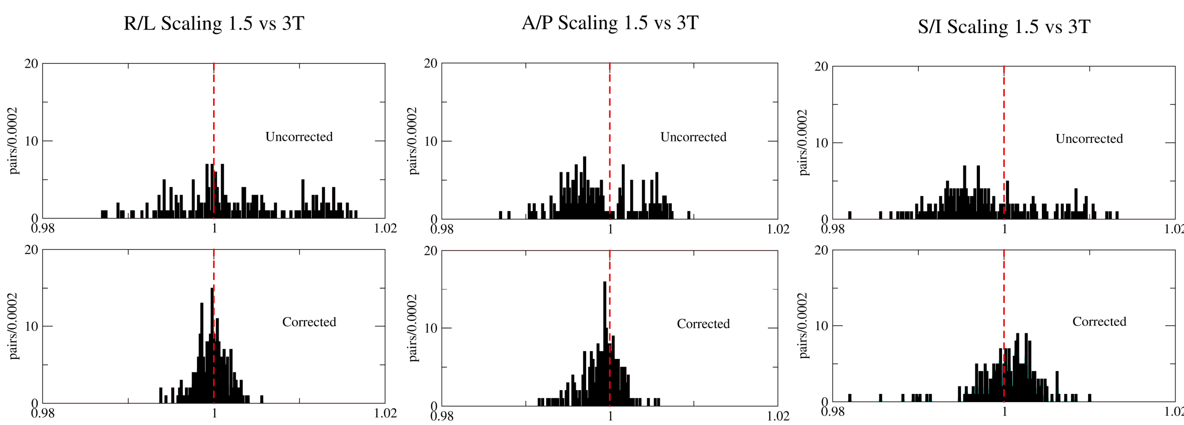

Figure 2 Scale factors in each cardinal direction from 206 image pairs where one image was acquired at 3T and one at 1.5T.

Results Figure 1 shows histograms for scaling in the three cardinal directions for 465 intra-subject image pairs with and without VSA. Within each subject the images were acquired on the same scanner with no major upgrades between scans. Images pairs were obtained across multiple scanners at multiple clinical sites. Each system was monitored with one and only one phantom. The distributions are narrower for images in which the voxel sizes have been adjusted. The means and standard deviations of the scale factor distributions are summarized in Table 1.

Analogous to Figure 1, Figure 2 shows data from 206 image pairs where one image was acquired at 3T and the other at 1.5T. The scan pairs in Figure 2 are cross-scanner and the variability with un-modified voxel sizes is broader. With VSA, the distribution in Figure 1 (and even more so Figure 2) becomes better centered and narrower, though some outliers persist. Summary statistics are included in Table 1.

Table 1:	Mean(SD) scale factors from pairwise co-registration		
Data set/ Direction	R/L	A/P	S/I
1.5T vs 1.5T no VSA	0.9998(0.0026)	0.9995(0.0023)	0.9997(0.0034)
1.5T vs 1.5T VSA	0.9994(0.0019)	0.9992(0.0018)	0.9999(0.0020)
3T vs 1.5T no VSA	1.0020(0.0085)	0.9984(0.0074)	0.9981(0.0062)
3T vs 1.5T VSA	0.9995(0.0047)	0.9986(0.0054)	1.0005(0.0044)

Table 1: Table 1 Summary statistics for scale factor distributions

Conclusion and Discussion Drifts or discontinuities in gradient calibration as well as other effects can change voxel size over time and across scanners. We conclude that phantom-based scaling of human images is an effective means of correcting for drifts or discontinuities in voxel size between imaging sessions. This approach has potential value in both single- and multi-center studies, particularly longitudinal studies, where consistency in image geometry is valuable. We note that the data presented were acquired under favorable conditions, i.e., there were no software upgrades or phantom changes. Given these conditions, we have shown that phantom measurements that are performed closely in time to their human scan counterparts capture information that can provide useful voxel size adjustments.

References

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