Proton density mapping: Removing receive-inhomogeneity using multi-coil information and T1 regularization

Aviv Mezer[1], Ariel Rokem[2], Trevor Hastie[2], and Brian Wandell[2]
[1]*Edmond and Lily Safra Center for Brain Sciences, The Hebrew University, Jerusalem, Israel,* [2]*Stanford university, CA, United States*

Introduction: Proton density (PD) is the most basic MRI measure, representing the amount of water protons in each voxel. Water content differs between tissue types, and changes during development and in disease. Knowledge of the water content is valuable for interpreting the biological significance of other MR parameters. Several MRI techniques estimate PD. Several groups assumed that all low frequency spatial variations arise from coil gain inhomogeneity. Volz et al.[1] add a regularizer based on a biophysical relationship between T1 and PD. Mezer et al. [2] estimate PD using multiple-channel data from the separate coils and regularize the solutions by measures of the between-channel correlations. Here we extend the prior work on PD mapping by combining these two methods. First, we apply ideas from parallel imaging to use multiple-channel data. Second, we use a regularizer based on the biophysical relationship between T1 and PD, as suggested by Volz et al. [1]. Using simulation we find that in the presence of noise, combining parallel imaging, smoothness assumptions, and the biophysical regularization together generates the most accurate estimates of both coil sensitivity maps and PD. We confirm the high accuracy when using multiple coils and T1-regularization on data from a phantom and a living human brain.

Methods: Data were obtained using a 3T GE Signa 750 MRI scanner. We obtained data using either a GE 8-channel or a Nova 32-channel receive-only head coils. The quantitative T1 and PD parameters were measured from Spoiled gradient echo (Spoiled-GE) images acquired with different flip angles (4o, 10o, 20o, 30o), TR = 20 ms and TE = 2.4 ms. The human brain scan measurements were made 1mm^3 resolution; the phantom data were acquired at 2 mm^3. The maps were calculated from the signal equation with a nonlinear least squares (NLS) fitting procedure.

Results: We simulate the Spoiled-GE brain signal with brain T1 and PD and coil sensitivities measured on a homogenous phantom (fig 1a-d). We estimated PD from the simulated data in five ways. The traditional approaches using mean M0 to estimate PD has an accuracy of R^2 = 0.52 and MAPE =19.2% and using the sum of squares has R^2 = 0.32 and MAPE =9.6%. Using only T1 regularization [1] (fig1e) improve the values, R^2 = 0.87 and the MAPE = 4%. The corresponding values for the correlation regularization n[2] are R^2 = 0.89 and MAPE = 3.8% (fig1f). Joining the two approaches, T1 and multiple coil information recovers the PD values with very high precision, R^2 = 0.99 and MAPE = 0.5% (fig1g). The spatial distribution of the percent error is shown by the colored insets. We test the accuracy of the new joined method with a homogeneous phantom (fig 2). We find that there is considerably more variance in the phantom before the correction (M0 image s.d. =0.3) than after (s.d.= 0.007). Last, we compared human brain PD estimates made using two different coils arrays (fig 3); one with 8-channels and the other with 32-channels that differ substantially in their coil sensitivity functions. The brain gray and white matter agree very well with R^2 = 0.9. This level of agreement is higher than we achieved before [2]. Importantly, the residual error distribution in space is even.

Conclusions: We find that multiple coil measurements combined with T1-regularization provides excellent quantification of PD in the living human brain, thus improving the current available approaches.

Figure 1

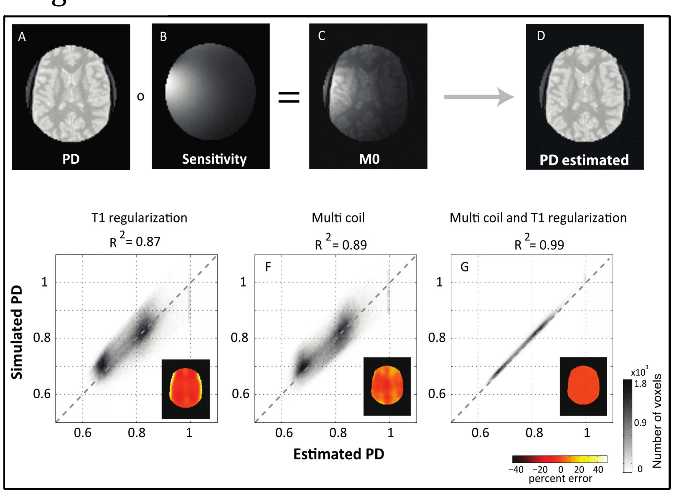


Figure 2

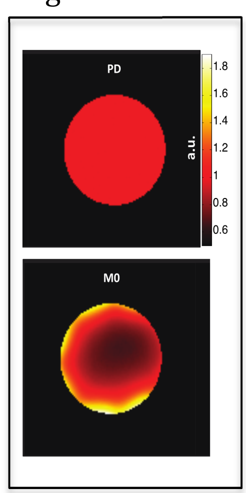
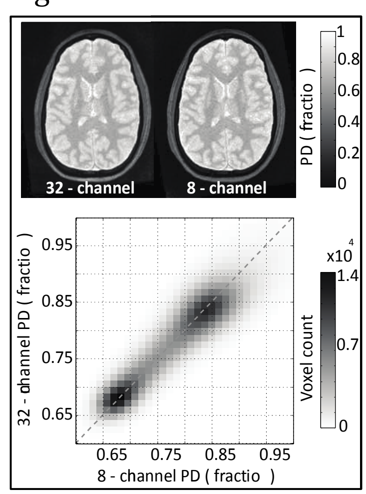


Figure 3



References

1. S. Volz, U. Nöth, and R. Deichmann, "Correction of systematic errors in quantitative proton density mapping," *Magn. Reson. Med.*, vol. 68, pp. 74–85, 2012.
2. A. Mezer, J. D. Yeatman, N. Stikov, K. N. Kay, N.-J. Cho, R. F. Dougherty, M. L. Perry, J. Parvizi, L. H. Hua, K. Butts-Pauly, and B. a Wandell, "Quantifying the local tissue volume and composition in individual brains with magnetic resonance imaging.," *Nat. Med.*, vol. 19, no. 12, pp. 1667–72, 2013.