SPLAT: SPatial LocalizAtion by T2-encoding

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Theory

The signal intensity in an image undergoing an exponential decay is given by

$$S_k(TE) = A_k \ exp(-TE_j / T2_k) \qquad [1]$$

where k is the pixel index, S_k is the signal at pixel k, A_k is a measure of the proton density, j is the echo index, TE_j is the echo time of echo j and $T2_k$ is a rate parameter. (NOTE: in this abstract we refer to $T2$ as the rate parameter, although $T2^*$ may be more appropriate). Supposing an image is acquired with 2X reduced field-of-view (FOV) in the phase encoding direction then the scan time will be reduced by half but there will be a characteristic foldover artifact, which is the super-position of two distinct pixel values half a FOV apart. Thus the folded signal (F) is given by

$$\begin{aligned} F(TE_j) &= S_1(TE_j) + S_2(TE_j) \\ &= A_1 \ exp(-TE_j / T2_1) + A_2 \ exp(-TE_j / T2_2) \end{aligned} \qquad [2]$$

Now suppose that 2 TEs have been measured then all the data can be expressed in matrix form as

$$\begin{bmatrix} F(TE_1) \\ F(TE_2) \end{bmatrix} = \begin{bmatrix} exp(-TE_1 / T2_1) & exp(-TE_1 / T2_2) \\ exp(-TE_2 / T2_1) & exp(-TE_2 / T2_2) \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \end{bmatrix} \qquad [3]$$

Given accurate values for $T2_k$ (such as from a $T2$ map) and a sufficiently well-conditioned matrix, it is possible to solve Eq 3 by a matrix inversion to get estimates of A_k at the two spatial locations. Once the A_k are known, an image with the required contrast – i.e. at a specific TE – can be recovered using Eq 1and the $T2$ map.

Results

Images were acquired using a multi-gradient-echo sequence (8 echo, 192×256 resolution, TR 100, $\alpha = 40°$). The $T2$ map was obtained from a full FOV (76 mm) scan made prior to the reduced FOV scan (38 mm). The TEs were 2.2, 3.9, 5.6, 7.3, 9.0, 10.7, 12.4 and 14.1 msec. Processing was performed on the magnitude images using MATLAB.

Fig 1: 1/$T2$ map

Fig 2: Folded image (TE = 7.3)

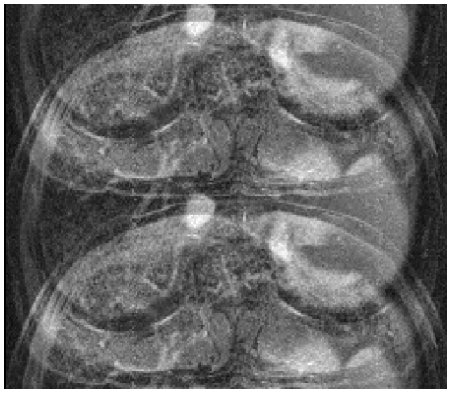

Fig 3: Unfolded image (TE = 7.3)

Discussion

This abstract demonstrates the use of SPatial LocalizAtion by $T2$-encoding (SPLAT) as a technique to reduce scan-time. The formalism has obvious similarities to SENSE (1), which spatially encodes the object using coil sensitivity functions and also similarities to gradient encoding, which spatially encodes the object using complex exponential functions.

The main disadvantages of SPLAT are: 1) the need to acquire an accurate $T2$ map and 2) the numerical instability of the matrix inversion. The former is somewhat mitigated by the possibility of using an arbitrary (i.e. fast) scan to measure the $T2$ map. The latter is more of a fundamental problem since aliased pixels that have the same $T2$ cannot be unaliased.

Reference

(1) Pruessmann et al. Sensitivity Encoding for fast MRI. *Magn Reson Med* 1999; **42**:952–962