Infimal Convolution of TV type functionals for reconstruction of highly accelerated dynamic MRI

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Speeding up the data acquisition for dynamic MRI applications, such as cardiac imaging, time-resolved flow-endcoding or dynamic contrast-enhanced applications (perfusion imaging, MRA), is an important topic in MRI, as it enables increased spatial or temporal resolution or decreases scan time. The key concept of data-undersampling leads to prominent artifacts for standard image reconstruction.
We propose to solve the image reconstruction problem by using an infimal convolution of total generalized variation type functionals (ICTV) as regularization. This functional forms a dedicated variational model for image sequences and is able to successfully exploit the high degree of spatio-temporal correlations and therefore yields high quality reconstructions. A simple form of the ICTV regularized reconstruction problem can be formulated as follows:

$$\min_u \frac{\lambda}{2}\|\mathbf{K}\ u - d\|_2^2 + \mathrm{ICTV}_\beta(u)$$

with

$$\mathrm{ICTV}_\beta(u) = \min_v \||\nabla(u-v)|_{\beta_1}\|_1 + \||\nabla v|_{\beta_2}\|_1$$

and

$$\mathbf{K} : u \mapsto (\mathcal{F}_t\,[c_j \cdot u_t])_{t=1,\cdots,N}^{j=1,\cdots,M}$$

$\mathbf{K}$ describes the frame-by-frame multi-coil MRI encoding operator with M calibrated sensitivities $\mathbf{c} = (c_j)_{j=1}^M$, $u = (u_t)_{t=1}^N$ the desired transverse magnetization for each of N time-frames t and d the reduced acquired multi-frame k-space data . ∇ denotes the spatio-temporal derivative and $|\cdot|_{\beta_1}$, $|\cdot|_{\beta_2}$ two norms applying a different weighting of the temporal derivative. The principle is illustrated for retrospectively undersampled CINE cardiac bSSFP sequences from a healthy volunteer for different acceleration factors.

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