Multi-Contrast MRI Reconstruction with Structure-Guided Total Variation

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Motivation and Purpose
- Magnetic resonance imaging (MRI) is a versatile technology with many different contrasts (e.g., see figure below for T1 and T2).
- MRI contrasts show similar structures due to same anatomy [1].
- We exploit redundancy, transfer structure from one contrast to another and reconstruct with less data.
- Shorter scan times: patient comfort, save time, dynamic imaging.

Visual Results
- From left to right: priors enhance visual quality.

What is Structure?
- Difficult to compare images of different contrasts.
- Base image structure on location or direction of spatial gradients.

Structure-Guided Total Variation
- Embed side information \( v \) in prior (regularization functional) with spatially varying matrix-field \( D : \Omega \to \mathbb{R}^{N \times N} \)
  \[
  \min_{u} \left\{ \frac{1}{2} \| A u - f \|^2 + \alpha \int_{\Omega} |D(x) \nabla u(x)| dx \right\}
  \]
- Reduces to normal total variation (TV) for \( D = I \).
- Isotropic structure (location) [2–4]:
  \[
  D(x) = \eta/|\nabla v(x)|_2
  \]
- Anisotropic structure (direction) [4–6]:
  \[
  D(x) = I - \xi(x) \xi(x)^T
  \]
- Dual formulation allows efficient algorithms [4]:
  \[
  \int_{\Omega} |D(x) \nabla u(x)| dx \leq \sup_{x \in \Omega} \left\{ \int_{\Omega} u(x) \ dx \right\} \sup_{x \in \Omega} \left\{ \int_{\Omega} |D^T(x) \varphi(x)| \ dx \right\}
  \]
- From left to right: priors enhance visual quality.

Quantitative Results
- Range (min to max), mean and median over 12 data sets.

Conclusions
- Exploiting redundancy (utilising either location or direction) allows reconstruction from less data.
- The anisotropic prior consistently outperforms the isotropic one, leading to less artefacts and a higher level of detail.

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References