Multi-Contrast MRI Reconstruction with Structure-Guided Total Variation

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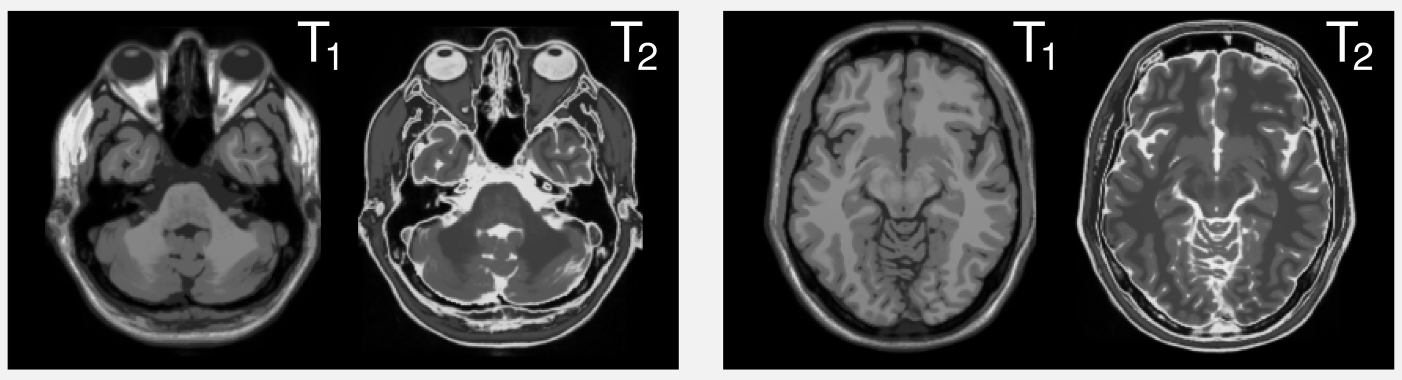
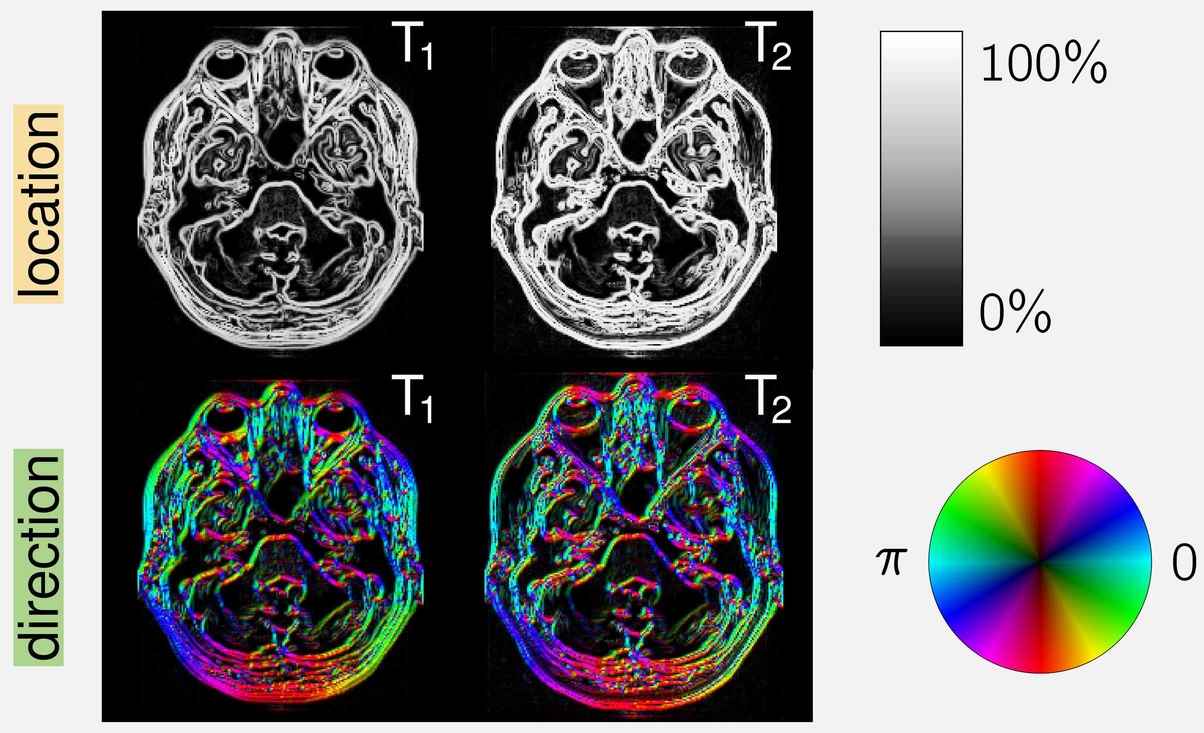
Motivation and Purpose

- magnetic resonance imaging (MRI) is a versatile technology with many **different contrasts** (e.g. see figure below for T_1 and T_2)
- 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



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 $\mathcal{D}: \Omega \to \mathbb{R}^{N \times N}$

$$\operatorname*{argmin}_u \left\{ \frac{1}{2}|Au - b|^2 + \alpha \int_\Omega |\mathcal{D}(x)\nabla u(x)| dx \right\}$$

- Reduces to normal total variation (TV) for $\mathcal{D} = \mathcal{I}$
- Isotropic structure (location) [2–4]:

$$\mathcal{D}(x) = \eta / |\nabla v(x)|_\eta \qquad \text{(wTV)}$$

with $|\nabla v(x)|_\eta = \sqrt{|\nabla v(x)|^2 + \eta^2}, \eta > 0$

- Anisotropic structure (direction) [4–6]:

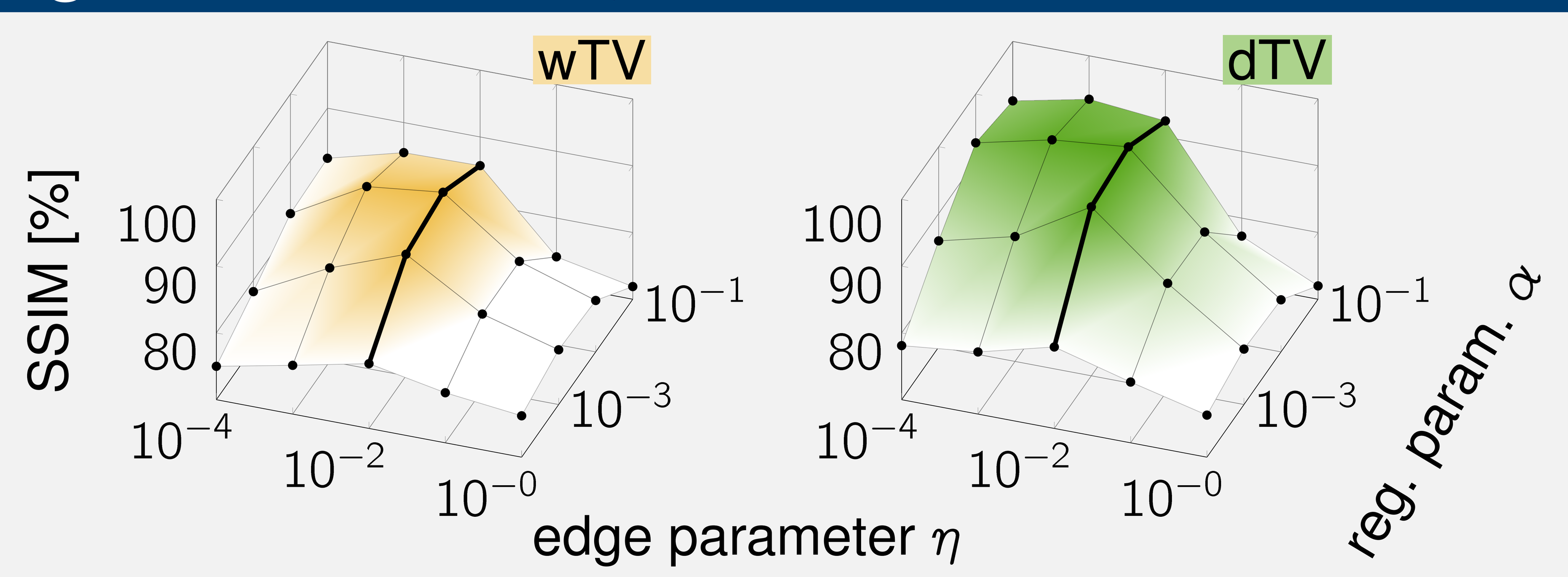
$$\mathcal{D}(x) = \mathcal{I} - \xi(x)\xi^T(x) \qquad \text{(dTV)}$$

with $\xi(x) = \nabla v(x) / |\nabla v(x)|_\eta$

- Dual formulation allows efficient algorithms [4]

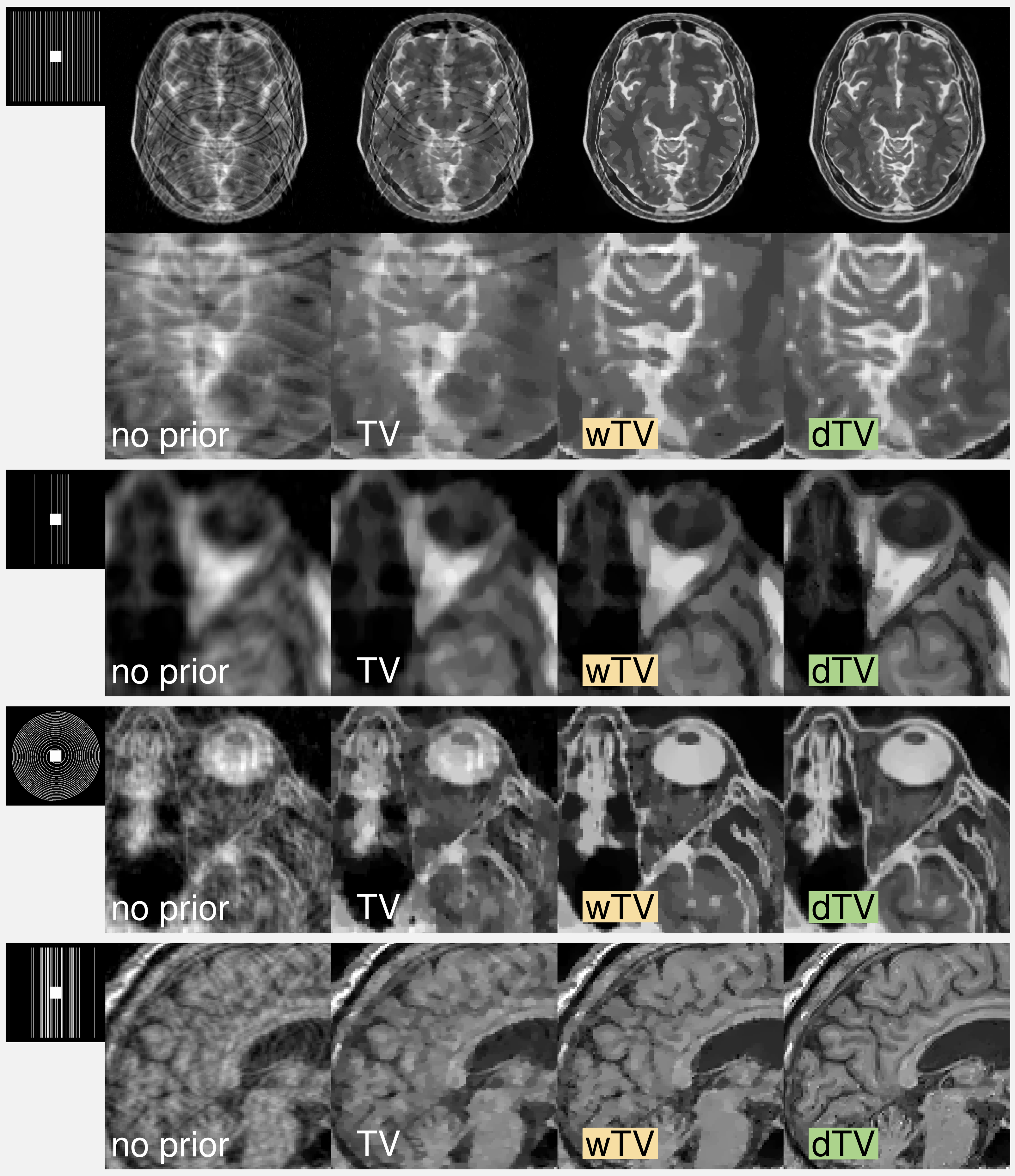
$$\int_\Omega |\mathcal{D}(x)\nabla u(x)| dx = \sup_{|\varphi(x)| \leq 1} \left\{ \int_\Omega u(x) \operatorname{div}\left[\mathcal{D}^T(x)\varphi(x)\right] dx \right\}$$

Edge Parameter η



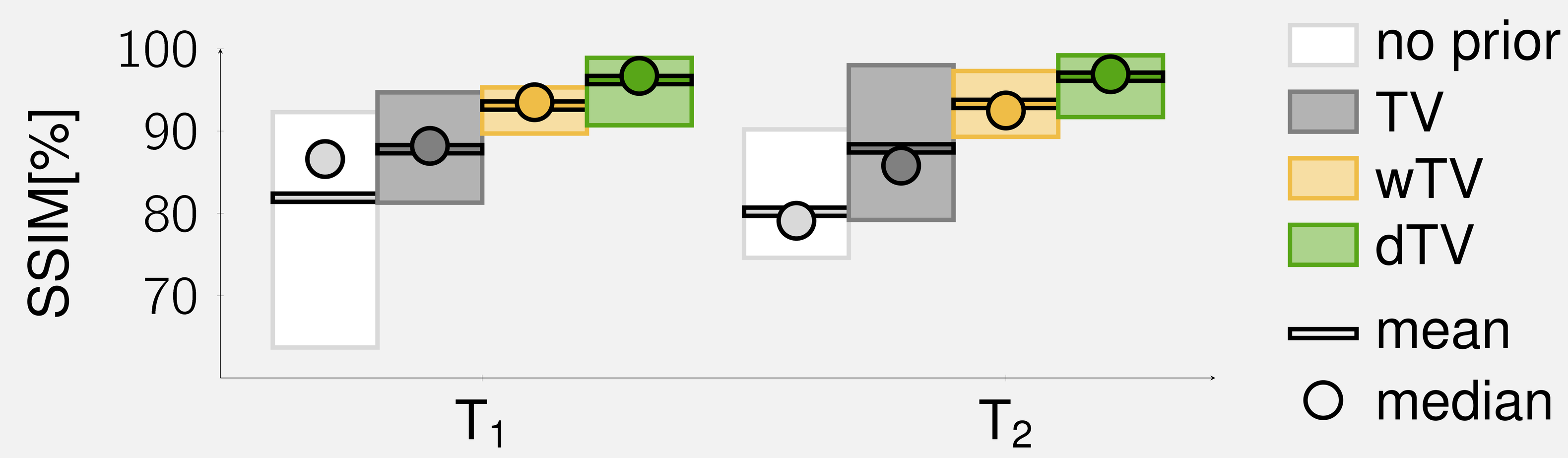
- Best results for $\eta = 10^{-2}$. Trade-off: regularization v structure
- For large η, both methods perform the same (as TV; not shown)

Visual Results



- From left to right: priors enhance visual quality

Quantitative Results



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

Conclusions

- Exploiting redundancy (utilizing 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

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