Enhanced Reconstruction of Compressive Sensing MRI via Cross-Domain Stochastically Fully-Connected Random Field Model

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Motivation/Objectives

• Low MRI acquisition times increase patient comfort and image quality
• Decrease MRI acquisition times through compressive sensing
• High quality reconstruction for diagnosis and screening of different types of cancer
Enhanced reconstruction of compressive sensing MRI via cross-domain stochastically fully-connected random field model

Program Number: 3405

Methodology:

- **Conditional Random Field Inference:**
  \[ P(Y|X) = \frac{1}{Z(X)} \exp(-\psi(Y|X)) \]
  where \( Z(X) \) is the normalization function and \( \psi(.) \) is described below.

- **Cross domain unary(\( \psi_u \)) and pairwise(\( \psi_p \)) energies:
  \[ \psi(Y|X) = \sum_{x \in \mathcal{X}} \psi_u(y, x) + \sum_{\{x,y\} \in \mathcal{E}} \psi_p(y, x) \]
  Where \( y \in \mathcal{Y} \) is a single state in the set \( Y \), \( x \in \mathcal{X} \) is the subset of clique structure in the set of \( \mathcal{C} \). \( x \in \mathcal{X} \) is the set of \( k \)-space observations.

The Cross-Domain Stochastically fully connected Conditional Random Field (CD-SFCRF) enforces original \( k \)-space (Frequency Domain) observations combined with spatial domain neighborhood consistencies to perform inference of states given compressive sensed \( k \)-space observations.

URL: Medical Imaging

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Existing Methods

- **Total Variation** (K. Block, et al. (2007))
  - Assumes piecewise smooth de-noising/reconstruction approach
- **L2 Minimization** (M. Lustig, et al. (2007))
  - Direct transformation from *k-space* into spatial domain
### Results (32% \textit{k-space sampling})

<table>
<thead>
<tr>
<th>Original Image</th>
<th>L2 Minimization (Compressive Sensed)</th>
<th>Total Variation Reconstruction (TV)</th>
<th>CD-SFCRF Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
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<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
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</tbody>
</table>

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Results with phantom data

Enhanced reconstruction of compressive sensing MRI via cross-domain stochastically fully-connected random field model

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<table>
<thead>
<tr>
<th>Sampling Rate(%)</th>
<th>L2 Min (dB)</th>
<th>TV (dB)</th>
<th>CD-SFCRF (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>24.63</td>
<td>26.22</td>
<td>27.90</td>
</tr>
<tr>
<td>10</td>
<td>27.75</td>
<td>30.81</td>
<td>34.63</td>
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<td>37.69</td>
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<td>32</td>
<td>38.53</td>
<td>40.56</td>
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<tr>
<td>36</td>
<td>39.71</td>
<td>42.18</td>
<td>42.68</td>
</tr>
</tbody>
</table>
Conclusions

- Better results for the proposed method show better tissue and structure details reconstructed while eliminating noise.
- PSNR analysis shows significant improvements at very low sampling rates.
- The proposed method fully utilizes available data for high quality reconstruction.
- Potential to decrease acquisition time significantly with little compromise in image reconstruction quality.