Zero-shot Prior Learning of Spatio-temporal Multi-echo/contrast MRI Reconstruction with Iterative Refinement

Tae Hyung Kim[1,2,3], Jaejin Cho[2,3], Borjan Gagoski[3,4], Zijing Dong[2,3], Fuyixue Wang[2,3], So Hyun Kang[1], Berkin Bilgic[2,3,5]

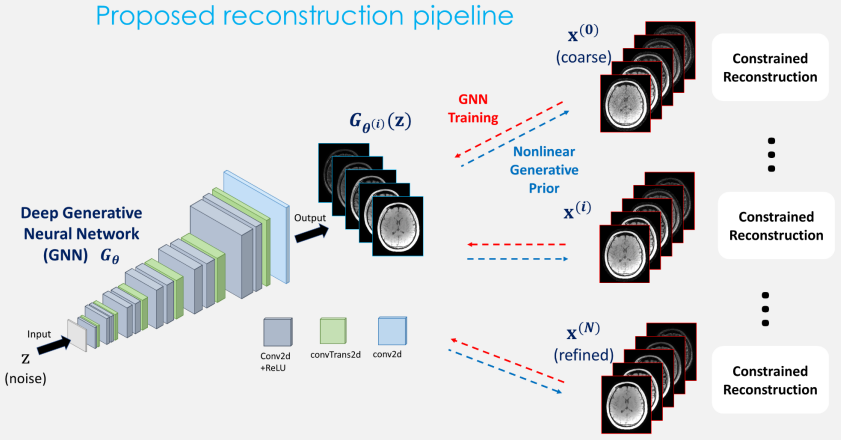
[1]Department of Computer Engineering, Hongik University, Seoul, Korea, [2]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, United States, [3]Department of Radiology, Harvard Medical School, Boston, MA, United States, [4]Fetal-Neonatal Neuroimaging & Developmental Science Center, Boston Children's Hospital, Boston, MA, United States, [5]Harvard/MIT Health Sciences and Technology, Cambridge, MA, United States

Target Audience Audiences interested in novel reconstruction methods and fast quantitative imaging

Purpose This work proposes a novel multi-echo/contrast MRI reconstruction using a zero-shot spatio-temporal deep generative neural network. Unlike conventional subspace methods employing linear representations of temporal signal evolutions, the proposed work exploits a nonlinear representation of the spatio-temporal MR signals using artificial neural networks and enables improved reconstruction quality. Unlike many existing deep learning-based techniques for multi-echo/contrast reconstruction, the proposed work takes advantage of an untrained network that does not require an external dataset for its training. As a result, the proposed method can provide robust multi-echo/contrast reconstruction with improved parameter estimation.

Theory and Methods The proposed method assumes the prior that the spatio-temporal multi-echo/contrast MRI can be nonlinearly generated from a generative neural network (GNN). The corresponding objective function follows

$$\hat{\mathbf{x}}, \hat{\theta} = \arg\min_{\mathbf{x},\theta} ||\mathbf{y} - \mathbf{A}\mathbf{x}||^2 + \lambda ||\mathbf{x} - G_\theta(\mathbf{z})||^2$$

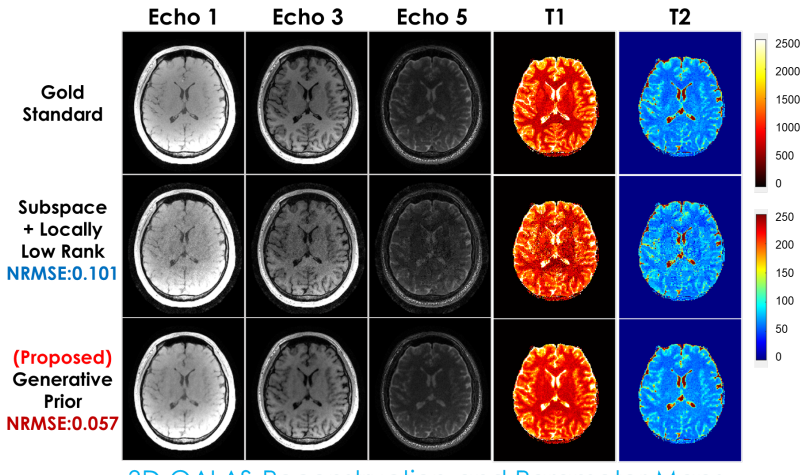


with the undersampled k-space data $\mathbf{y}$, the forward model $\mathbf{A}$ (Fourier, coil sensitivity, and undersampling), the underlying multi-echo/contrast MR images $\mathbf{x}$ (to be reconstructed), a random representation vector $\mathbf{z}$ and the generative neural network $G_\theta(\mathbf{z})$ (parameterized by θ) for the nonlinear spatio-temporal prior. The multi-echo MR images $\mathbf{x}$ and the GNN parameters θ are jointly optimized using the alternating minimization,

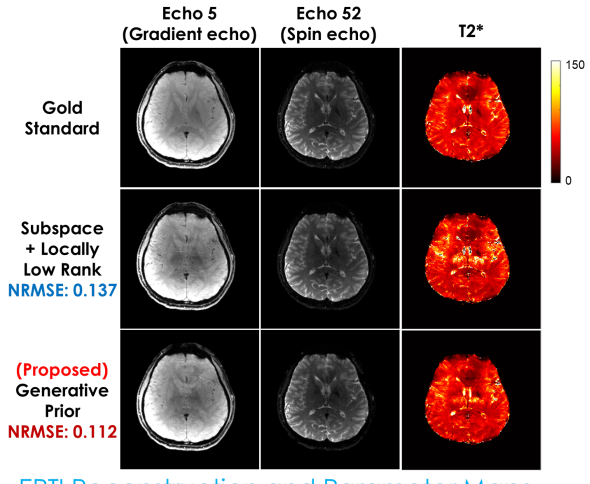
$$\mathbf{x}^{(i+1)} = (\mathbf{A}^H\mathbf{A} + \lambda\mathbf{I})^{-1}(\mathbf{A}^H\mathbf{y} + \lambda G_{\theta^{(i)}}(\mathbf{z}))$$
$$\theta^{(i+1)} = \arg\min_{\theta} ||\mathbf{x}^{(i+1)} - G_\theta(\mathbf{z})||^2,$$

where the second step suggests the proposed zero-shot training of the GNN, which is trained and iteratively refined using the intermediate MR images $\mathbf{x}^{(i+1)}$ instead of requiring an external training dataset.

Results The proposed method was evaluated using a 3D-QALAS (3D-quantification using an interleaved look–locker acquisition sequence with a T2 preparation pulse) dataset with five contrasts and an EPTI (echo-planar time-resolved imaging) dataset with 120 echoes. The following figures display the experiment results with the reconstructed images and the estimated parameter maps.



3D-QALAS Reconstruction and Parameter Maps (R=12x, 5 Echoes, 32 channels)



EPTI Reconstruction and Parameter Maps (R=24x, 120 Echoes, 32 channels)

Discussion and Conclusion We introduced a novel zero-shot prior learning for spatio-temporal multi-echo/contrast MRI reconstruction. The experiment results indicate the advantages of the proposed method against conventional techniques for fast and robust multi-echo/contrast MR imaging and quantitative parameter mapping.

Data/Code:https://anonymous.4open.science/r/Multiecho_Recon_Deep_Generative_Prior-8403/