An Unsupervised Deep Learning Framework for Image Super-Resolution for Late Gadolinium Enhanced Cardiac MRI

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Introduction: Cardiac magnetic resonance (MR) imaging provides high resolution in-plane information, however, they are known to have low through-plane resolution (i.e., slice thickness). This issue cannot be resolved through interpolation, as it results in artifacts such as blurring and loss of information. Hence, we present an unsupervised deep learning framework for image super-resolution (SR). This method leverages the information learnt from the high resolution (HR) in-plane data to improve the through-plane resolution.

Methods: We conducted our experiments on a 154 3D late gadolinium-enhanced MRI (LGE-MRI) dataset (110: training, 15: validation and 29: testing) featuring isotropic voxel spacing of 1x1x1 mm^3. To mimic low-resolution (LR) MRI data, we blur the images and downsample them via bicubic interpolation with the scale factor of 2-4. We employed an autoencoder network to reconstruct HR short-axis 2D images from LR LGE-MRI dataset. The input data to the autoencoder are randomly extracted 64x64 patches of short-axis images. This trained autoencoder model is used to estimate HR long-axis data, such that the reconstructed 3D images have improved through-plane resolution.

Results: Our proposed method achieved a mean structural similarity index (SSIM) of 0.9897 and 0.9433 using a scale factor of 2 and 4, respectively, compared to 0.9835 and 0.9229, respectively, using bicubic interpolation alone. Similarly, we achieved a mean PSNR of 47.96 and 35.92 using a scale factor of 2 and 4, respectively, compared to 47.05 and 33.14, respectively, using bicubic interpolation alone. Lastly, the resulting super-resolution images featured less blurring and information loss than the bicubic interpolated images, resulting in smoother segmentation masks featuring reduced stair-step artifacts.

Conclusion: We described a CNN-based image SR algorithm for improved through-plane resolution in cardiac LGE-MRI data. We will extend this method to 4D cine cardiac MRI dataset with poor through-plane resolution to obtain HR 3D cine MR images.