Neural Network Based Super Resolution Improves Cortical Segmentation Accuracy in Ultrahigh Resolution Imaging

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Abstract

With the raising of deep learning methods on medical imaging tasks, super resolution(SR) was well investigated to improve image resolution to facilitate more applications. One of them is segmentation task in Ultra high-field MRI, served as a way of augmenting synthetic data, SR could help to not only improve model accuracy by expanding the trainset, but also was shown to perform better than traditionally interpolated images when fed to segmentation network. Especially in Ultra-high resolution(<0.6mm), lack of accuracy is problematic when a high-precision segmentation is required such as for the estimation of cortical thickness.

In this work, we developed a Generative Adversarial Network(GAN) to perform SR task, which also generates images different resolution that was more accurately segmented.
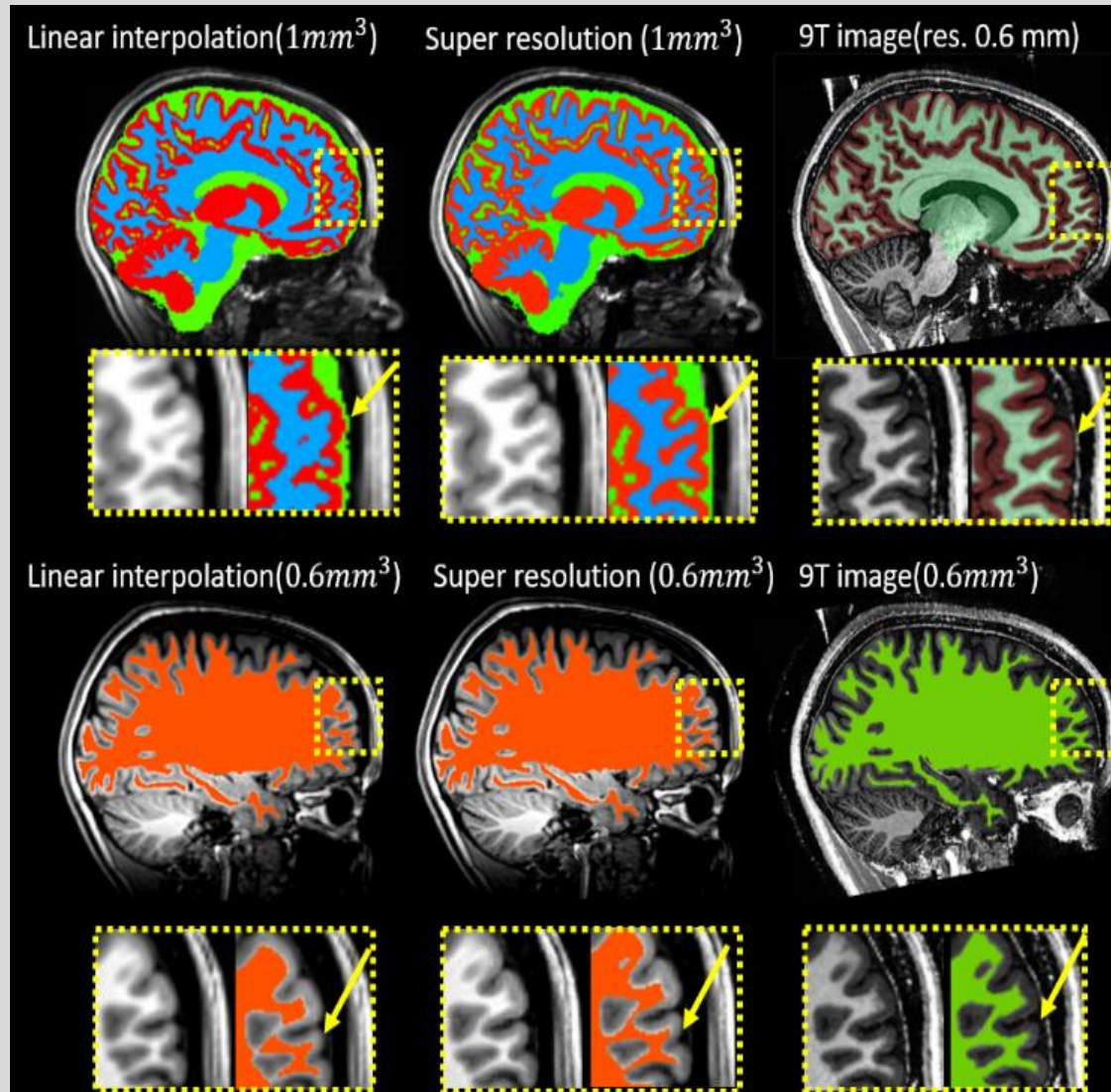
Method

Data

During training phase, 184 anatomical T1w images from Human Connectome Project acquired at 3 Tesla at 1mm resolution were used. The images were first linearly down-sampled to 2mm then paired with their ground truth for the training. During validation, a 3T and 9T image from the same subject at resolution of 1.2mm and 0.6mm were used. These data were acquired at the University Hospital of Tübingen and the department of Magnetic Resonance Imaging, Max Planck Institute for Biological Cybernetics, Tübingen, Germany, respectively.

Algorithm

Generative Adversarial Network(GAN) were chosen as the super-resolution model architecture, as a 3D customized adaption of ESRGAN, including a feature extractor of frozen resnet-10.

Result I: Super resolution

A. The super resolution result compared with 3T and 9T ground truth. B. Workflow comprised of super-resolution GAN and segmentation network.

Result II: Segmentation

Segmentation results comparison between super-resolution image and linearly interpolated 3T image both in 1 mm (upper row) and 0.6 mm (lower row) resolution, referred to 9T ground truth. The comparison in sagittal plane (zoom-in comparison in yellow dashed box, pointed by arrow) between linearly interpolated (left) and super resolved image (middle), with its 9T image as ground truth (right).

Results

As was shown in Result II, the results of both up-scaled images, where segmentation of super-resolution image show less incorrect labeling in gray matter (the zoom-in views are included in yellow dashed box), both in 0.6mm(upper row)and 1mm resolution(lower row). The arrows mark regions on the brain where the white matter segmentation showed higher accuracy when applied to the super-resolution image.
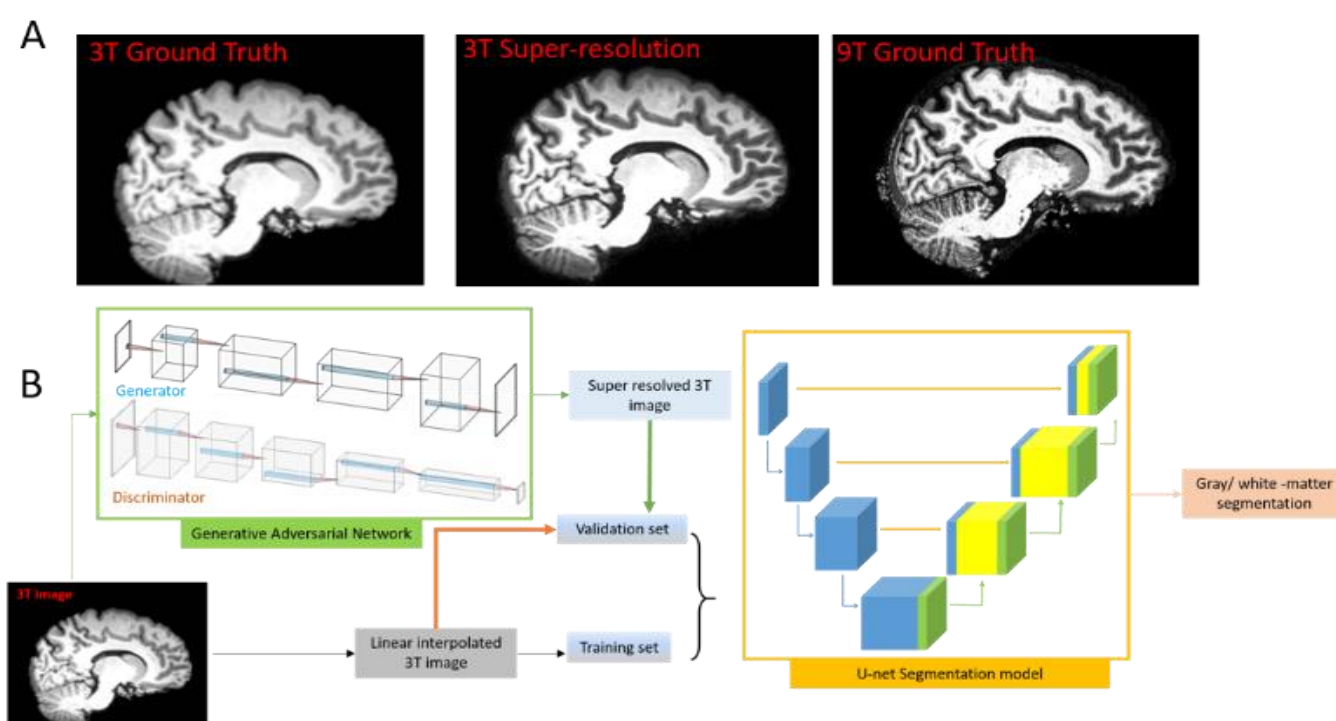
Conclusion

Overall, super-resolution MR images looks more realistic and retains detailed anatomical information, moreover, it performs less prediction error than linear interpolation images in high-resolution cortical segmentation. However, it remains challenging and interesting to find out the types of specific features which the super-resolved images indirectly learned to improve the segmentation result.

Additionally, the training phase in medical imaging models still suffer from lack of training data. Thus a pre-trained weight will be significantly helpful for more task-specific models to fine-tune.

Reference

1) Van Essen, D.C., Smith, S.M., Barch, D.M.,Behrens, T.E., Yacoub, E., Ugurnil. K., Consortium, W.M.H., et al., (2013), The WU-Minn human connectome project: an overview. Neuroimage 80, 62-79.
2) Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair,S., Courville, A., Bengio, Y., (2014), Generative adversarial nets, in: Advances in neural information processing systems, pp. 2672-2680.
3) Dong, C., Loy, C.C., He, K., Tang, X., (2016a), Image super-resolution using deep convolutional networks. IEEE transactions on pattern analysis and machine intelligence 38, 295-307.
4) O. Ronneberger, P.Fischer, T. Brox, (2015),U-Net: Convolutional Networks for Biomedical Image Segmentation, Medical Image Computing and Computer-Assisted Intervention (MICCAI), vol 9351, pp. 234-241.