

Adaptive 3D Augmentation in StyleGAN2-ADA for High-Fidelity Lung Nodule Synthesis from Limited CT Volumes

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Generative adversarial networks (GANs) typically require large datasets for effective training, which poses challenges for volumetric medical imaging tasks where data are scarce. This study addresses this limitation by adapting adaptive discriminator augmentation (ADA) for three-dimensional (3D) StyleGAN2 to improve generative performance on limited volumetric data. The proposed 3D StyleGAN2-ADA redefines all 2D operations for volumetric processing and incorporates the full set of original augmentation techniques. Experiments are conducted on the NoduleMNIST3D dataset of lung CT scans containing 590 voxel-based samples across two classes. Two augmentation pipelines are evaluated—one using color-based transformations and another employing a comprehensive set including geometric, filtering, and corruption augmentations. Performance is compared against a slice-wise 2D StyleGAN2-ADA baseline by assessing generation quality with Kernel Inception Distance (KID) and Learned Perceptual Image Patch Similarity (LPIPS). Results show that volumetric ADA substantially enhances training stability and reduces mode collapse, even under severe data constraints. Aggressive augmentation improves the realism of generated 3D samples and better preserves anatomical structures relative to 2D slice-wise training. These findings demonstrate that adaptive 3D augmentations effectively enable high-quality synthetic medical image generation from extremely limited volumetric datasets.

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