Comparative Analysis of Single Image Super-Resolution (SISR) Techniques in Medical Imaging

Single Image Super-Resolution (SISR) is pivotal in medical imaging, enhancing the resolution of images from modalities such as MRI and CT scans. Among the various approaches, Generative Adversarial Networks (GANs), Vision Transformers, and lightweight models have shown significant promise. Below is a comparative analysis of these methodologies.

1. GAN-based Methods

GANs have been instrumental in generating high-frequency details in super-resolved images. The SRGAN model, for instance, introduced adversarial loss to encourage the generation of high-frequency details, producing images that were perceptually closer to the ground truth. However, GAN-based models often suffer from instability during training and may introduce artifacts that compromise the accuracy of medical images, where precise detail is crucial.

2. Vision Transformer-based Methods

Vision Transformers have emerged as a powerful alternative, leveraging self-attention mechanisms to capture global context effectively. The Residual Dense Vision Transformer (RDVT) integrates residual dense connections with Vision Transformers to achieve efficient SISR. This method has demonstrated superior performance across multiple medical imaging modalities, achieving high Peak Signal-to-Noise Ratio (PSNR) scores while maintaining a relatively small model size.

3. Lightweight Models

In scenarios where computational resources are limited, lightweight models offer a viable solution. Recent studies have explored lightweight SISR techniques tailored for medical imaging, aiming to reconstruct high-resolution images from low-resolution counterparts while enhancing visual quality without imposing significant computational burdens.

Performance Comparison

A study comparing various SISR methods, including EDSR, RDN, RCAN, HAN, SwinIR, and RDST variants, reported the following average PSNR (dB) and SSIM values across four medical imaging datasets:

Method	PSNR (dB)	SSIM
EDSR	32.55	0.9184
RDN	32.57	0.9241

RCAN	32.81	0.9224
HAN	32.33	0.9120
SwinIR	33.24	0.9287
RDST	33.42	0.9299

Note: PSNR = Peak Signal-to-Noise Ratio; SSIM = Structural Similarity Index

The RDST model, a Vision Transformer-based approach, achieved the highest PSNR and SSIM values, indicating superior image reconstruction quality.

The choice of SISR method in medical imaging should be guided by specific requirements such as desired image quality, computational resources, and the criticality of preserving anatomical details. Vision Transformer-based methods like RDST have demonstrated superior performance in terms of image quality metrics. However, lightweight models may be preferable in resource-constrained environments, and GAN-based methods, while powerful, require careful implementation to avoid artifacts that could compromise diagnostic accuracy.