Edge-Aware Image Denoising via Adaptive Weighted Fractional-Order Total Variation under Cauchy Noise

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***Abstract*—Image denoising under non-Gaussian heavy-tailed noise remains a fundamental challenge in imaging science. Traditional total variation (TV) methods, while effective for Gaussian noise, tend to oversmooth textures and fail under Cauchy degradations. Fractional-order regularizers extend classical TV by introducing nonlocal interactions and improved texture preservation. This work proposes a novel adaptive weighted fractional-order total variation (FOTV) model incorporating a Cauchy fidelity and an edge-aware weighting strategy. The approach unifies a robust Cauchy fidelity term and a spatially weighted fractional-order total variation (FOTV) regularizer in the Caputo sense. The fractional-order operator promotes nonlocal smoothness, and the adaptive weight function automatically adjusts regularization near edges, enhancing texture preservation. The nonconvex minimization problem is handled by a split Bregman iteration combined with a half-quadratic reformulation of the Cauchy fidelity, yielding efficient and stable updates. Theoretical analysis guarantees well-posedness of the discrete problem. Experimental results on natural and medical images demonstrate that the proposed model achieves higher PSNR and SSIM values and better visual performance than existing TV-based models, especially in the presence of strong Cauchy noise.**

***Index Terms*—Fractional-order total variation, Cauchy noise, Caputo derivative, split Bregman method, half-quadratic reformulation, image denoising, adaptive regularization.**