Rotation-Invariant Non-Local Means Based on Riesz Pyramid Features and SURE Parameter Selection

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Non-local means (NLM) is a recent and powerful denoising method that applies adaptive averaging based on similarity between patches in the image. It has been observed that performing a linear projection of the patches on a dimensionality-reduced subspace (e.g., using principal component analysis) improves the quality and the speed of the technique. Interestingly, the dominant principal components resemble atoms of traditional wavelet and Fourier bases.

Here we revisit NLM and show how it can be equivalently seen as a filterbank operation followed by feature extraction. We then generalize the concept and introduce the multiscale and rotation-covariant Riesz wavelet pyramid to constitute dimensions of the feature space. In addition, we use steering properties of the Riesz operator to reorient each of the patches (or at least its representation in feature space) according to a reference orientation. This way we obtain a rotation-invariation NLM method.

We have also derived an explicit analytical expression for Stein's unbiased risk estimate (SURE) in the context of NLM with shift-variant linear transformations of the patches. The SURE-NLM allows to monitor the MSE for restoration of an image corrupted by additive white Gaussian noise without knowledge of the noise-free signal. Moreover, the SURE comes with low computational cost. The experimental results demonstrate the accuracy of the SURE and its successful application to tune the parameters for NLM and the Riesz wavelet pyramid.