Image Quality Improvement Using Shift Variant and Shift Invariant Based Wavelet Transform Methods: A Novel Approach

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ABSTRACT

The concept of Multi-Scale Transform (MST) based image de-noising methods is incorporated in this paper. The shortcomings of Fourier transform based methods have been improved using multi-scale transform, which help in providing the local information of non-stationary image at different scales which is indispensable for de-noising. Multi-scale transform based image de-noising methods comprises of Discrete Wavelet Transform (DWT), and Stationary Wavelet Transform (SWT). Both DWT and SWT techniques are incorporated for the de-noising of standard images. Further, the performance comparison has been noted by using well defined metrics, such as, Root Mean Square Error (RMSE), Peak Signal-to-Noise Ratio (PSNR) and Computation Time (CT). The result shows that SWT technique gives better performance as compared to DWT based de-noising technique in terms of both analytical and visual evaluation.

KEYWORDS
Discrete Wavelet Transform, Spatial Domain Filtering, Transform Domain Filtering

INTRODUCTION

Over the decades, digital image plays an indispensable role in day-to-day life applications such as geographical information systems, astronomy, and satellite television. Images acquired by image sensors are generally contaminated, various factors responsible for affecting the quality of images, are imperfect instruments, data acquisition process, and interfering natural phenomena. Thus, de-noising is highly imperative for image data analyses which can be achieved by applying an efficient de-noising technique to compensate for image data corruption.

Many researchers have realized the importance of Multi-Scale Transform (MST) techniques in the field of image de-noising which is more efficient compared to spatial domain based de-noising technique (Jain, 1989, Donoho & Johnston, 1994; Zhang & Wells, 2000; Chipman et al., 1997; Jansen, 2000). The shortcomings of the Weiner filter were pointed out and eliminated by researcher Donoho and John stone using Wavelet based de-noising technique (Jain, 1989, Donoho & Johnston, 1994). In spatial-scale domain based technique, first, an image is decomposed by applying MST on each
source image, and then employ the optimal threshold condition to construct a composite multi-scale representation of the de-noised image. The de-noised image is recovered through an inverse MST. The commonly used MST techniques include the Laplacian Pyramid (LP) (Jain, 1989; Donoho & Johnston, 1994; Zhang & Wells, 2000) and DWT (Chipman et al., 1997; Jansen, 2000). Further, DWT has many advantages over LP methods in terms of localization and direction (Chipman et al., 1997; Jansen, 2000; Lang et al., 1995). Also, it is observed that DWT suffers from shift-variance and limited directionality. Thus, in order to overcome the limitation of DWT, the concept of SWT was introduced. The SWT is shift-invariant technique which is desirable in image analysis applications, such as, edge detection, contour characterization, and image de-noising and image enhancement.

Thus, the main goal of this paper is to evaluate the performance of DWT and SWT techniques for the de-noising of images corrupted with different types of noises. The introductory knowledge of commonly occurring noises such as Gaussian noise, Poisson noise, Speckle noise, Salt and Pepper noise, etc. (Yang et al., 1995) are discussed in subsequent paragraph:

**Gaussian Noise**

Gaussian is also called as electronic noise, as it arises in amplifiers or detectors. It is uniformly distributed over the signal. This implies that each pixel in the noisy image is equal to the sum of the true pixel value and a random Gaussian distributed noise value. It is caused by natural sources, such as discrete nature of radiation of warm objects and thermal vibration of atoms (Yang et al., 1995).

It has a bell-shaped Probability Distribution Function given by,

\[
P(g) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(g-\mu)^2}{2\sigma^2}}
\]

where, \( g \) represents the gray level, \( \mu \) is the average or mean of the function, and \( \sigma \) is the standard deviation of the noise.

**Salt and Pepper Noise**

It is an impulse type of noise, which is also referred as intensity spikes, caused generally due to errors in data transmission. The corrupted pixels are assigned alternatively to the maximum or to the minimum value, giving the image a “salt and pepper” like appearance. In case of 8-bit image, the typical value for pepper noise is 0 and for salt noise is 255. It is also caused by impairments of pixel elements in the camera sensors, timing errors in the digitization process, or faulty memory locations.

**Speckle Noise**

Speckle noise is a multiplicative noise. It occurs in almost all coherent imaging systems such as acoustics, laser, and Synthetic Aperture Radar (SAR) imagery (Yang et al., 1995). Its probability density function follows gamma distribution, and is given by,

\[
F(g) = \frac{g^{\alpha-1} e^{-\frac{g}{\alpha}}}{\alpha^{-\alpha} \Gamma(\alpha)}
\]
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