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Comparative Analysis of an Efficient Image Denoising Method for Wireless Multimedia Sensor Network Images in Transform Domain

R. Dhaya

Professor, Department of Computer Engineering, King Khalid University, Abha, Kingdom of Saudi Arabia

E-mail: dhayavel2005@gmail.com

Abstract

In recent years, there has been an increasing research interest in image de-noising due to an emphasis on sparse representation. When sparse representation theory is compared to transform domain-based image de-noising, the former indicates that the images have more information. It contains structural characteristics that are quite similar to the structure of dictionary-based atoms. This structure and the dictionary-based method is highly unsuccessful. However, image representation assumes that the noise lack such a feature. The dual-tree complex wavelet transform incorporates an increase in transform data density to reduce the effects of sparse data. This technique has been developed to decrease the image noise by selecting the best-predicted threshold value derived from wavelet coefficients. For our experiment, Discrete Cosine Transform (DCT) and Complex Wavelet Transform (CWT) are used to examine how the suggested technique compares the conventional DCT and CWT on sets of realistic images. As for image quality measures, DT-CWT has leveraged superior results. In terms of processing time, DT-CWT gave better results with a wider PSNR range. Further, the proposed model is tested with a standard

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digital image named Lena and multimedia sensor images for the denoising algorithm. The suggested denoising technique has delivered minimal effect on the MSE value.

Keywords: WMSN, Image denoising methods

1. Introduction

A fully developed wireless multimedia sensor network includes sensor nodes, which are equipped with cameras to collect and distribute images and videos to and from other nodes present in the network. Because camera sensors produce digital pictures and movies that are then altered by noise throughout each of the recording, sending, and retrieving operations, digital images and videos are developed through digital image capturing sensors that provide imperfections [1-4]. The consequence is that poor lighting, change of illumination, fog, rain, and other weather issues make numerous dots visible in a picture. To execute the functions of detection and segmentation, a picture that is clear and noise free is essential. Additionally, many image denoising techniques are used to suppress the noise present in the images with the primary goal of protecting the object in the data without decreasing the quality of overall image [5-9]. Figure 1 shows some standard images for testing various transform methods.

The adoption of a noise reduction technique is required to extract speech from the systems with just one microphone. There are many issues in the sensor module, they are processing delay, signal distortion, and audio signals resulting from external noise are all issues that enhance at the cost of other factors that come from the noisy domain [10]. Furthermore, an improved noise spectrum estimate is required for the SS technique. A voiceless section detector is needed in practice to provide good noise reduction. Also, here a noise reduction technique uses linear prediction to consider the undesirable side effects.

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Figure 1. Sample Standard Images

White noise is accurately and rapidly quantified by using the technique shown above since the coefficients of linear predictors converge to produce white noise in the prediction error signal. The efficacy of noise reduction diminishes, however, when the noise is colored [11].

Every pixel in the original picture may be treated separately in the spatial domain, and each has a relationship with its surrounding pixels and associated filter matrix. Although there are several denoising methods for spatial domain image processing, an adaptive median filter for noise suppression is provided [12].

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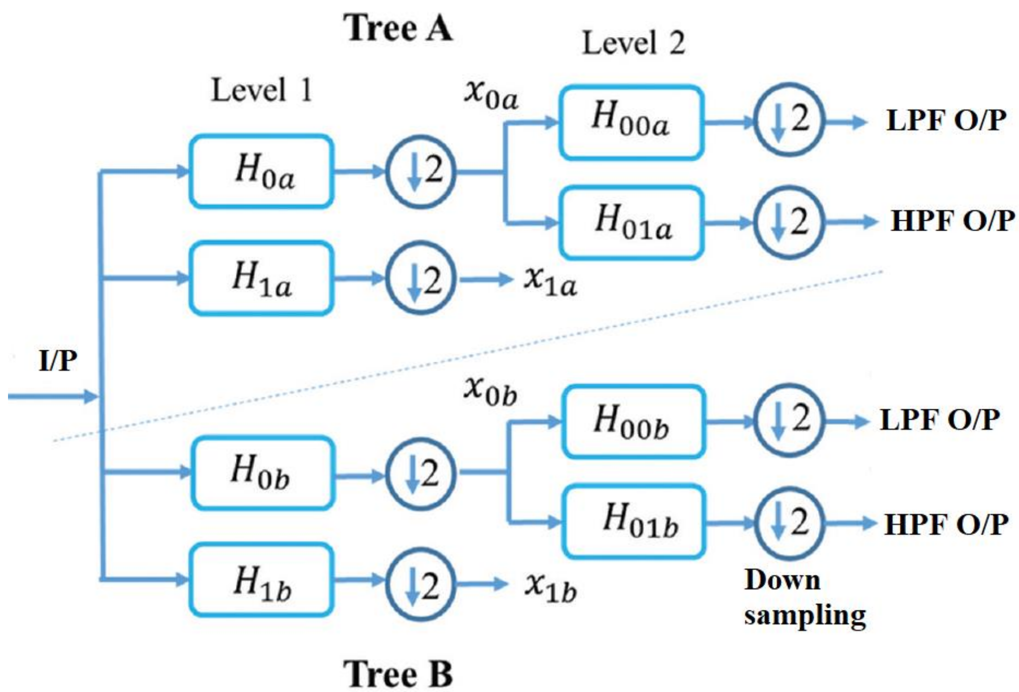

Figure 2. Dual Tree Complex Wavelet Transform (DT-CWT)

While these approaches have certain disadvantages, such as a high computational cost, nevertheless they are very effective. Furthermore, recent techniques have attempted to integrate the median filter with impulse detection in order to make up for the median filter's limitations. However, the performance of the impulse detector must be maintained. Other methods, such as mean-based filters, may be used in place of heavy computation when it exists. Recently, several fuzzy logic techniques have been suggested for picture noise reduction.

Even if DWT was utilized, it has several challenges. This data is affected by a lack of shift-invariance, insufficient directional information, and a lack of phase information. Applying the Stationary Wavelet Transform (SWT) throughout the course of the last year has helped to eliminate

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the challenge of shift variation. However, SWT may boost the power of wavelet-based picture denoising significantly but it is computationally costly due to its higher redundancy [13].

Research Gap

Complex Wavelet Transforms (CWTs) have been recently used to address DWT issues by utilizing a variety of mathematical methods. Many studies have claimed Dual-Tree Complex Wavelet Transform (DT-CWT) as one of the most efficient versions of CWT. It provides six-dimensional texture information with a lower degree of redundancy. An effective image denoising technique for wireless multimedia sensor network applications use the DT-CWT for performing real-time image processing. The proposed approach has two novel features. The first solution is to use Structural Similarity Index Measure (SSIM) as a fidelity term instead of the reconstruction error. This recommendation is made because it correlates to anatomical similarities in the human visual system (HVS), which makes it more likely to result in better outcomes.

2. Organization of the Research

The remaining part of this research article is organized as follows: section 3 discusses about the existing research works on the efficient image denoising methods. Section 4 discusses about the proposed work for image denoising methods. Section 5 presents the obtained results as well as their discussion. The conclusion and future tasks of the wireless sensor network research will be discussed in the final section of this research article.

3. Preliminaries

In order to decrease background noise, Zhang and Xie's de-noising technique employs DCT and sparse representation. An over-complete vocabulary learnt from the noisy image may be used to efficiently characterise the image's content in this manner. However, the dictionary

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includes a significant number of meaningless atoms, which reduces the effectiveness of picture sparse representation, wherein the number of these atoms present in the dictionary is decreasing [14].

It was also suggested by Zhang et al. to use adaptive sparse representation for de-noising. By using the K-SVD technique, an over-complete vocabulary has been learned from the test picture. This process is susceptible to noise, and when there is a significant amount of noise is present in the picture, the rebuilt image may fluctuate [15].

Zhou and Luo proposed a novel technique for acquiring over-complete vocabulary, which they dubbed the K-LMS (K-Least Mean Square). Adopting the LMS decomposition method produces step lengths that are inflexible and stiff may result in an unusually high number of steady-state errors [16].

Generally, three main algorithms were used in the construction of an artificial immune system, which comprised negative selection, clonal selection, and immune networks. A superior approach to decrease data quantities is presented by the theory of the immune network system, which is more suited for image pattern recognition. This method uses the IN algorithm for pattern recognition, which gives the capability to quickly identify internal data representation and as a result a reduction in data size can be achieved by utilizing memory cell representation [17].

A rapid road categorization and orientation estimate technique was reported by Z. Zhu, et al. to utilize Omni-view pictures and neutral networks. Face identification is efficiently handled by utilizing a learning-based approach for super-resolved face pictures, which incorporates a PCA-based previous model [18].

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Kingsbury developed the DT-CWT approach to properly reconstruct it by providing the benefits of complex wavelets. It exhibits a very distinct directionality in two and higher dimensions and is only weakly invariant in terms of shifts [19].

4. Proposed Methodology

The input images are collected from the multimedia sensor output image and also it performs image registration and preprocessing to obtain the better PSNR and SSIM values. Following the hard threshold function procedure (shown in figure 4), analysis and synthesis filter banks are employed to deconstruct and rebuild the image features.

4.1 Design of DT-CWT

This is an expansion of DWT that adds key characteristics of the wavelet. From the perspective of using real-valued filter coefficients, the software utilizes an analytic filter to conduct the wavelet analysis. Figure 4 shows overall proposed framework. This solution alleviates the issues associated with DWT at the expense of reduced redundancy and sparse effects [20]. With DWT, three directional sub-bands are created for each pixel for displaying picture characteristics that are oriented at 90, 45, and 0 degrees (x). Figure 3 shows DT-CWT real and imaginary part orientation angle of the coefficient location.

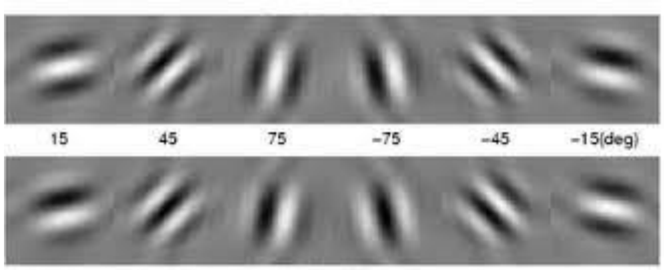

Figure 3. DT-CWT Real & Imaginary Part Orientation

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4.2 Computation in DT-CWT

The DT-CWT of an image may be computed by individually applying the filter bank to the two dimensions and then extend the result to the whole picture. One or more trees (such as trees a, b, c, and d) are required for analysis, while several trees (such as trees a, b, c, and d) are required for synthesis, which has shown in the figure 2. Also soft threshold is taking place in the proposed work. The wavelet co-efficient gets adjusted with soft threshold value [21, 22].

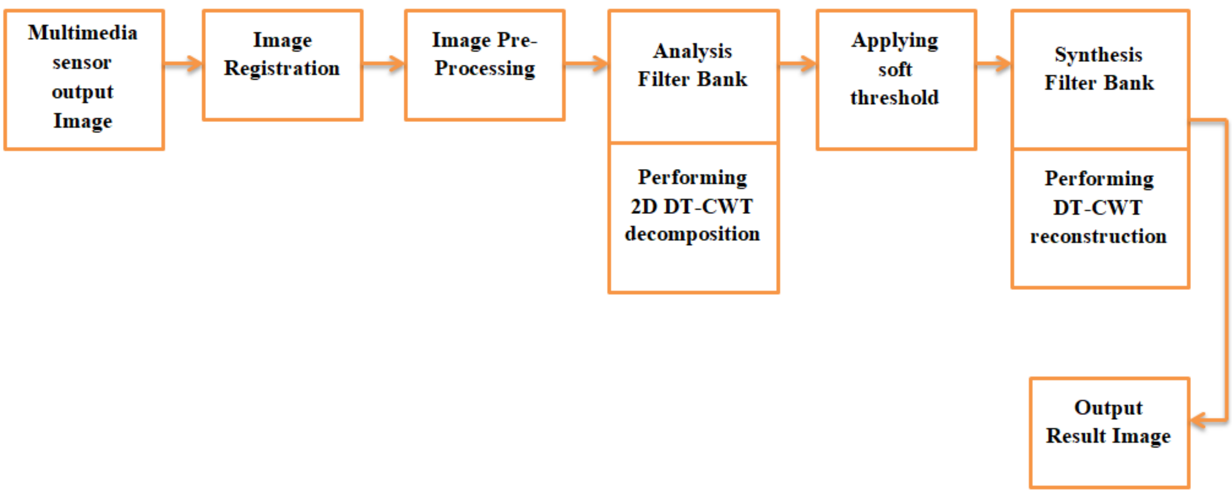

Figure 4. Overall Proposed Framework

4.3 Down sampling process

This process decomposes the signal of the input picture by using two separable 2D DWT branches (a) and (b) in parallel. For each filtering step, there is a down sampling operation followed by a DT-CWT tree application to rows (x) and subsequently to columns (y) [23-25]. It is defined with a combination of imaginary part as follows;

$$(h_x + jg_x)\,(h_y + jg_y) = (h_x h_y + g_x g_y) + j(h_x g_y + g_x h_y)$$

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5. Results & Discussion

This section displays the results of the proposed image denoising application that was created by running DT-CWT on a group of indoor-outdoor scenes. We also demonstrate the effectiveness of the proposed approach by comparing it to DCT and CWT when applied to the same collection of pictures.

Figure 5. Obtained Results by Various Algorithms

The result of suggested method is shown in Figure 5A. The output of DWT, DCT, CWT, first level, and second level transforms are shown in Figure 5B, E, F, G, and H. The ground truth picture in Figure 5D is used to calculate the performance measures of different methods. Figure 5C depicts a noisy view of the Lena. Our suggested method, DT-CWT, demonstrates the existence of sparse free effects in the Lena image, as shown in Figure 5D.

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Figure 6. Multimedia Sensor Image Reconstruction

Figure 6 shows multimedia sensor image reconstruction with our proposed work. Our proposed work has suppressed the sparse effect in the noise representing the effect. Our proposed work performs well in sparse suppression.

Table 1. Calculation of Performance Metrics

S.No	Transform Domain	PSNR	MSE	SSIM	Average processing Time (sec)
1	CWT	21.41	0.167	0.661	2.4892
2	DCT	24.57	0.093	0.840	6.3353
3	Proposed DT-CWT	32.98	0.004	0.912	3.8138

Three picture quality measures are used to quantify the suggested denoising method's performance: the Peak Signal-to-Noise Ratio (PSNR), and the Mean Square Error (MSE) and

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structure similarity index (SSIM). Denoised and original scene pictures are used to calculate image quality measures.

$$PSNR = 10 * \log\left(\frac{255^2}{MSE}\right)$$

$$MSE = \frac{1}{M * N}\sum_{i=1}^{N}\sum_{j=1}^{M}\left[I(i,j) - \hat{I}(i,j)\right]^2$$

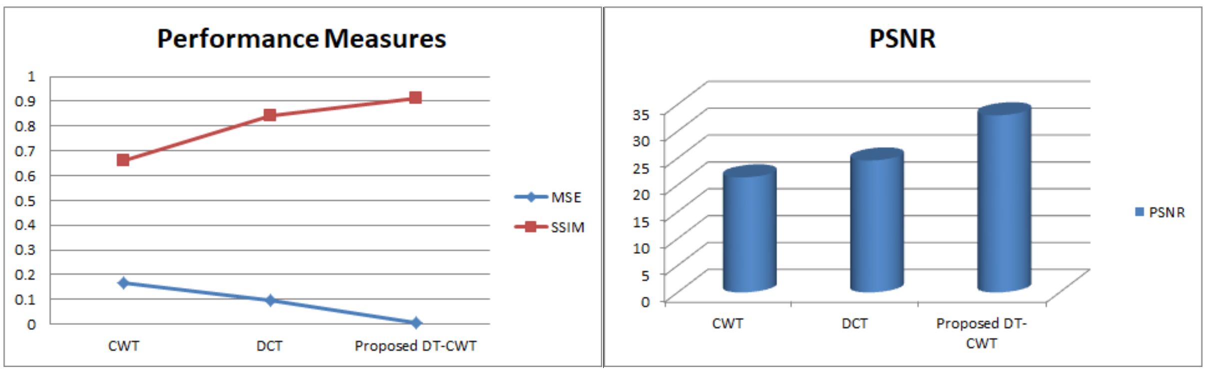

Figure 7. Overall Performance Measures

Figure 7 shows overall performance measures of the proposed work. SSIM is a novel method for assessing picture quality. Brightness, contrast, and structure are all measured when determining the picture quality. According to the SSIM, it may be characterized as follows:

$$SSIM = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

SSIM is more aligned with the properties of the human visual system, which include brightness, contrast, and structure. It is in the range of 0 to 1. The pictures are more similar in structure, when it is closer to 1. The proposed algorithm proves SSIM value is nearer to 1 than

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other techniques. Various image denoising techniques used in real-time image processing applications need processing time to be a critical measurement especially sensor output images. It may be computed on the same hardware setup described above by executing the programs of various picture denoising techniques in MATLAB R2012a.

6. Conclusion

Thus, the suggested model outperformed other methods in terms of PSNR and SSIM. Additionally, our test picture is becoming sparse as a result of the multimedia sensor output. The suggested approach is utilized to reduce the noise caused by the temperature of sensor devices. Other techniques have failed to produce a sparse-free effect from the input pictures resulting in a blurring impact on the rebuilt images. The visual results in the future will be further enhanced with PSNR measurements. Additionally, the two-dimensional DT-CWT method may improve the efficiency of noisy images that are processed by sensor network devices can indicate its efficacy in reducing the images through wireless sensor devices. Additionally, the pictures from the sensor network may be utilized as a preprocessing step to optimize the operations. While this study used real-world time images to validate the proposed technique, future work will include further validation by utilizing the images obtained through wireless multimedia sensor networks that are connected to other devices. In the transform domain, these images have a significant degree of sparse impurity [26-29].

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Author's biography

R. Dhaya is currently a Professor, in the Department of Computer science and Engineering at King Khalid University, in the Kingdom of Saudi Arabia. His major area of research includes Image and Video Processing Algorithms, Computer Vision, Motion Analysis, Stereo Vision, Object Recognition, computer graphics, photo interpretation, image retrieval, Embedded Image Processing and Real-time image and video processing applications.

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