Digital Watermarking for Image Authentication using Spatial-Scale Domain based Techniques

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Abstract:**This paper aims in presenting a thorough comparison of performance and usefulness of concept of spatial-scale domain based techniques in digital watermarking in order to sustain the ownership, security and true authentication. Spatial-scale based image watermarking techniques provides the information of 2-Dimensional (2-D) signal at different scales and levels, which is desirable for image watermarking. Further, these techniques emerged as a powerful and efficient tool to overcome the limitation of Fourier, spatial, as well as, purely frequency based techniques. The spatial-scale based watermarking techniques, namely, Contourlet Transform (CT), Non Sub-sampled Contourlet Transform (NSCT), Stationary Wavelet Transform (SWT) and Discrete Wavelet Transform (DWT) have been selected for watermarking process. Further, the comparison of performance of the selected watermarking techniques have been carried out in terms of different metrics, such as Peak Signal-to-Noise Ratio (PSNR), Root Mean Square Error (RMSE), Tamper Assessment Factor (TAF) and Mean Structural Similarity Index (MSSIM). Analysis of result shows that multi-directional and shift-invariant NSCT technique outperforms the SWT and DWT based image watermarking techniques in terms of authentication, better capture quality, and tampering resistance, subjective and objective evaluation.**

Keywords**: Image Watermarking, Spatial-scale Domain Filtering, Non Sub-sampled Contourlet Transform**

I. INTRODUCTION

In recent years, with the increasing use of web applications, rapid growth in digital technique and unforced copying, tampering and sharing of digital data, copyright protection for multimedia data has become a matter of concern. Digital watermarking (DW) come out as a efficient and powerful tool to protect the multimedia data from copyright infringement. In DW, an undetectable signal "mark/logo/symbol" is inserted/embedded into the host image, which exclusively identifies the ownership [1]. The inserted data can be later detected in the multimedia to make an affirmation about the data. After embedding the watermark, there should be no perceptual degradation. These watermarks should not be removable by illegal person and should be strong against intentional and unintentional attacks. Digital watermarks remain undamaged during transmission, offers us to guard our ownership rights in digital form [2-3]. Further, DW techniques can be broadly classified into two categories: First, Spatial Domain (SD) methods Second, Transform Domain (TD) methods [4-7]. In SD, the simplest method is based on embedding the watermark in the least significant bits (LSB) of image pixels. However, these techniques are not efficient for image compression and other image processing applications, whereas, TD based watermarking techniques exhibits better image fidelity [4].

Spatial-scale domain based watermarking techniques, such as DWT, SWT, CT and NSCT, overcome the limitation of the spatial, Fourier and frequency domain based techniques. However, it is found that the problem associated with the DWT and SWT is poor directionality, while, CT suffers from shift-variance, due to involvement of down sampling and up sampling process. Thus, to resolve the limitation of DWT, SWT and CT, NSCT has been introduced [10-13]. NSCT is the shift-invariant and multi-direction technique, which is advantageous in applications, such as, digital watermarking, image de-noising, edge detection, etc [10-13].

Further, wide range of literature have already been published on image watermarking techniques, however, there is no such literature published, which provides a comparative study of different spatial-scale techniques in terms of different datasets, qualitative and quantitative analysis. Thus, the comparison of performance of spatial-scale techniques in terms of different scenario is the central theme of this study.

II. IMAGE WATERMARKING TECHNIQUES

Spatial-scale domain based image digital watermarking techniques, such as, NSCT, SWT and DWT, have been selected and implemented. The brief description of DWT, SWT and NSCT based watermarking techniques are discussed below:

2.1 Image watermarking by DWT

In the DWT algorithm, the Low Pass (LP) and High Pass (HP) filters have been used for the decomposition of image. These filters divide the image into two bands i.e., LP and HP bands [5-9]. The former performs an averaging operation to extract the average information of the image, whereas, the later performs a differencing operation to extract the lines, points and edges information. Thereafter, the output of filtering operation is decimated by 2. A 2-D transformation is achieved by performing two individual 1-D transforms, along row and column separately [8-9]. This operation decomposes the image into four bands namely LL, LH, HL and HH

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respectively. The watermark embedding and extraction procedure followed by DWT technique has been explained in the section 2.4.

2.2 Image watermarking by SWT

In order to resolve the problem of shift-variance, associated with DWT, SWT based watermark technique has been introduced [2-5]. In SWT, the filter is up-sampled by inserting zeros between the filter coefficients, thereby eliminating the down-sampling step. It uses a 2-D filter bank to produce two images, of which one is an approximation image and other is a detailed image, also called the wavelet plane. A wavelet plane contains the horizontal, vertical and diagonal information between 2^j and 2^{j-1} resolution. Further, the size of the approximation images is same as that of the original image. This is due to the fact that the filters at each stage are up-sampled by inserting zeros between the coefficients, which in turn make the size of the image equal [4-7]. The watermark embedding and extraction procedure followed by SWT has been explained in the section 2.4.

2.3 Image watermarking by NSCT

[6] proposed a newly method of image representations named Non Sub-sampled Contourlet Transform (NSCT), to get rid of the shortcomings of wavelets, curvelets and contourlets. NSCT can incarcerate the essential geometrical information of images, along with the provision of multi-directions and shift-invariance, which are required for the effective analysis of an image [6-8]. Also, it provides better regularity and frequency selectivity over CT. Further, it consists of two filter banks one is used to provide multi-scale decomposition and other is used to provide directional decomposition of an image into different scale and directions.

The watermarking algorithm consists of two parts, one is watermark embedding and other is watermark extraction. The general methodology adopted for the watermark embedding and extraction using DWT, SWT and NSCT based DW techniques can be summarized as follows:

i) *Watermark Embedding Process*

Decompose the cover image and watermark image into a Contourlet and wavelet domain. After embedding the cover image with watermark image, the wavelet and contourlet transform is subjected to the watermarked image to produce the final protected watermarked image.

ii) *Watermark Extraction Process*

Watermark extraction can be considered as the inverse process of watermark embedding process. The watermark is recovered from the watermarked image by using the defined key, followed by inverse wavelet and contourlet process.

III. EVALUATION CRITERIA

In order to assess the quality of the watermarked image other than simple qualitative assessment of the images. Metrics such as, RMSE and PSNR have been used for the assessment of generated watermarked images [9-10]. The mathematical representation of these measures have been discussed below:

i) *RMSE*

RMSE is one of the most usable and effective metric for the estimation of quality of image when reference image is present. RMSE is a good quality measure of accuracy [9].

$$\mathrm{RMSE} = \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\frac{\left(F(i,j)-R_o(i,j)\right)^2}{m\times n}} \quad \ldots(1)$$

where, m, n indicate the size of the image is $m \times n$. $F(i,j)$ and $R_o(i,j)$ indicate the watermarked and reference image. Smaller the value of RMSE, lesser is the difference between the images.

ii) *PSNR*

PSNR is one of the most well-known metric, used to quantify the distortion of the watermarked image compared with the reference image. The value of PSNR should be large for better output [10].

$$\mathrm{PSNR} = 10\log\left(\frac{255}{\mathrm{RMSE}}\right)^2 \quad \ldots(2)$$

iii) *MSSIM*

The overall structural quality of an image is obtained by computing the average of SSIM values over all the windows. If N is total number of windows then Mean Structural Similarity Index (MSSIM) [14] is given by (Eq. 4). The Structural Similarity (SSIM) Index between the original (X) and watermarked (Y) image will be given by Eq (3) as:

$$\mathrm{SSIM}(X,Y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \ldots(3)$$

where, c_1,c_2 are constants used to avoid un-stability. X and Y are the original and extracted images.

$$\mathrm{MSSIM} = \frac{1}{M}\sum_{j=1}^{M}\mathrm{SSIM}(x_j,y_j) \ldots(4)$$

iv) *TAF*

[15], [16] and [17], has demonstrated the utility of Tamper Assessment Factor (TAF) in digital watermarking, to ensure the quality of extracted signal by comparing the extracted signal with respect to original signal.

TAF provides a simple way to find out the extent of tampering in terms of spectral and geometrical information. It represents the number of bits of the extracted image those are different from the original image [18]. Further, the extent of tampering of the extracted image is computed using a TAF. The TAF is defined by (Eq. 5)

$$\mathrm{TAF}(R_o,F) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} R_o(i,j)\oplus F(i,j)}{m\times n} \ldots(5)$$

where, m, n indicates the size of the image. $F(i,j)$ and $R_o(i,j)$ indicate the extracted and the original image at position (i,j), respectively. $\oplus$ is an Exclusive-OR (Ex-OR) operator.

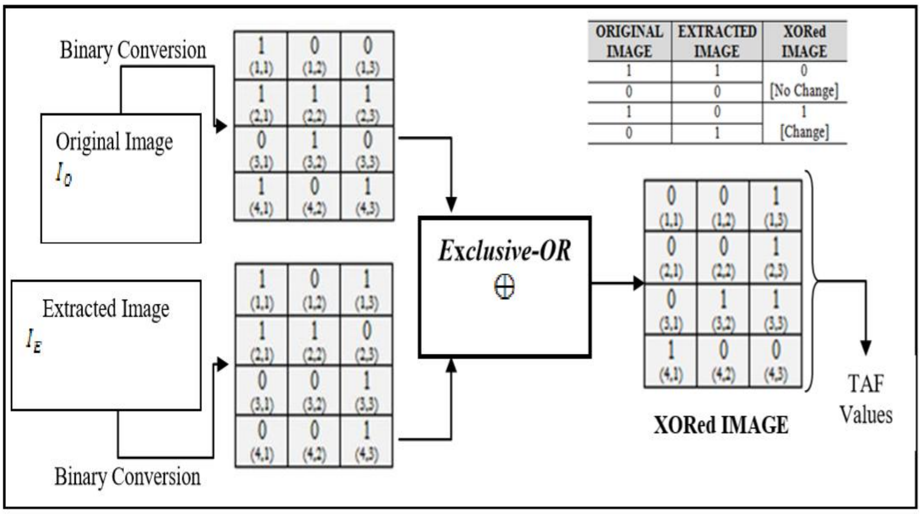

Fig. 1 Representation of TAF procedure using Exclusive-OR theory.

A low value of TAF would indicate that the extracted image is more similar to the original image. From Figs. 1 & 2, the theory of TAF can be well interpreted, analyzed, explained and understood.

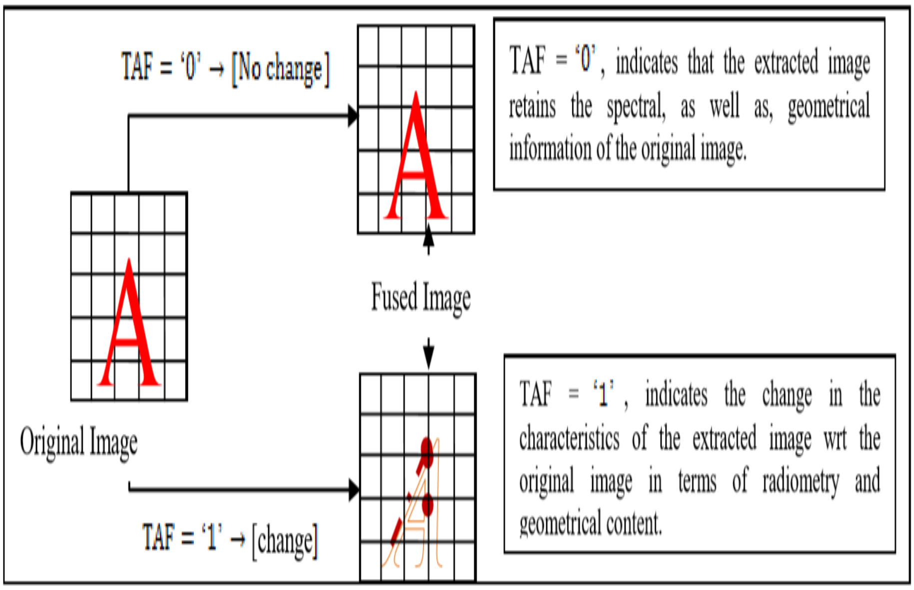

Fig. 2 Example to highlight TAF theory.

IV. EVALUATION OF RESULTS AND DISCUSSION

A thorough analysis of the comparison of performance of the DW techniques has been carried out in terms of different scenario. Further, for the implementation purpose, image of size 512×512 has been taken.

4.1 *Visual (Qualitative) Analysis*

Qualitative analysis is one of the well-known techniques to assess the effectiveness of any DW techniques. The extracted images are subjectively assessed in terms of different Colour Radiometry (CR), Shape of the object (SO) and Edge Sharpening (ES).

Table 1 Assessment of quality of image by qualitative method

Absolute Measure	Relative Score
Excellent (E)	5
Good (G)	4
Above Average (AA)	3
Average (A)	2
Poor (P)	1

For visualization purposes, watermark techniques have been categorized from "Excellent" to "Poor", as shown in Table 1.

Analysis of Recovered Image generated from different watermarking techniques

Fig. 3 shows the recovered watermark image generated by different watermarking techniques for dataset DS.

DS-I		
 **LENA**	 **ORIGINAL WATERMARK**	 **WATERMARKED IMAGE**
 **EXTRACTED WATERMARK BY DWT**	 **EXTRACTED WATERMARK BY SWT**	 **EXTRACTED WATERMARK BY NSCT**
DS-II		
 **BARBARA**	 **ORIGINAL WATERMARK**	 **WATERMARKED IMAGE**
 **EXTRACTED WATERMARK BY DWT**	 **EXTRACTED WATERMARK BY SWT**	 **EXTRACTED WATERMARK BY NSCT**
DS-III		

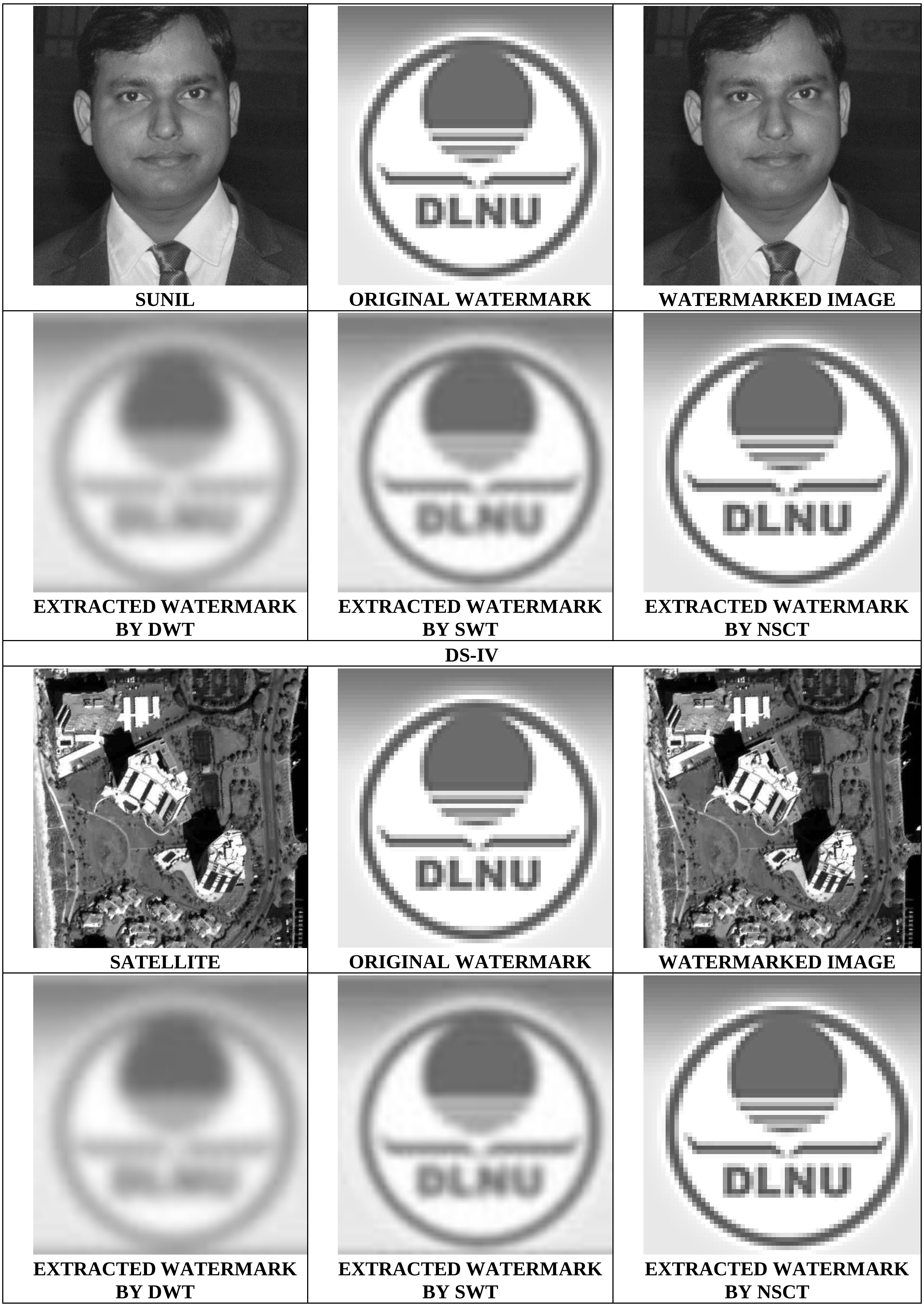

Fig. 3 Extracted watermark images by different watermarking techniques for different Datasets

From Fig. 3, it is found that the recovered images generated by NSCT based watermarking technique, for different datasets exhibits the good structural details, when compared to the original image, followed by CT, SWT and DWT techniques. However, colour radiometry in the recovered images generated by NSCT is slightly lighter in comparison to original image. This is followed by CT, SWT and DWT based DW techniques. Amongst the techniques, the recovered image generated by DWT technique exhibits lower spatial quality. This is due to the sub-sampling process associated with DWT technique, leading to the introduction of artifacts, when images are zoomed in to observe very minute objects.

Table 2 Comparison of watermark techniques on the basis of visual object detection

Image	Digital Watermarking Technique											
	DWT			SWT			CT			NSCT		
	CR	SO	ES	CR	SO	ES	CR	SO	ES	CR	SO	ES
LENA	2	2	2	2	2	2	2	3	2	4	3	3
BARBARA	2	2	2	2	2	3	3	2	3	3	3	3
SUNIL	1	2	2	2	2	2	2	2	2	3	3	2
SATELLITE	2	2	2	3	2	2	3	2	3	4	4	3

From Table 2, it has been observed that NSCT based technique exhibits the highest performance for different datasets, when compared to CT, SWT and DWT based watermarking techniques. In other words, the recovered watermark with NSCT appears smoother and exhibits good preservation of edges. Thus, subjectively, it can be concluded that NSCT technique works well and yields the better performance in terms of preservation of colour radiometry and geometrical similarity information. This is followed by CT, SWT and DWT based watermarking techniques.

4.2 Quantitative Analysis

The investigation, analysis and comparison of performance of different DW techniques have been carried out using objective indicators (Table 3. It is observed that there are various factors which causes loss of information and degrades quality of image. The recovering of watermark in the degraded image is performed using NSCT, CT, SWT and DWT techniques. The recovered watermark image which will best preserve the colour radiometry, sharpness and geometrical information of the original image is the one that has satisfied the following conditions (Table 3).

Table 3 The ideal and error value of different quantitative indicators

S. No.	Metric	Ideal Value	Error Value
1	RMSE	0	> 0
2	PSNR	NA	> 1
3	MSSIM	1	> 0 and < 1
4	TAF	0	> 0

Based on these metrics, the performance and accuracy of the watermarking techniques will be carried out.

4.2.1 Analysis based on RMSE

Generally, lower value of RMSE corresponds to a greater accuracy measure in terms of image fidelity. The results of RMSE generated by different DW techniques for different datasets are tabulated in Table 4.

Table 4 Comparison of RMSE for different datasets

DS		RMSE Metric		
		Watermark Technique		
		DWT	SWT	NSCT
DS-I	LENA	3.646	3.315	2.247
DS-II	BARBARA	5.702	4.921	3.734
DS-III	SUNIL	4.651	3.562	1.562
DS-IV	SATELLIT	6.572	5.618	3.448

a) Analysis of DS dataset

Analysis of result shows that watermark image are effectively recovered using NSCT based watermarking technique, as indicated by low RMSE value in comparison to CT, SWT and DWT based DW techniques. Amongst DW techniques, DWT based watermarking technique exhibits low performance in terms of RMSE metric. This is due to the sub-sampling effect associated with DWT technique, results in introduction of false information such as, existence of square blocks, making the linear features zigzag in the image.

Thus, it can be concluded that NSCT based DW technique exhibits the highest performance in terms of sharpness and geometrical information, when compared to CT, SWT and DWT watermarking techniques. Further, NSCT based DW technique is suitable for recovering of watermark images, when compared to other based watermarking techniques.

4.2.2 Analysis based on PSNR

Generally, higher values of PSNR reflect less amount of image distortion. The analysis of PSNR values for different watermarking techniques are tabulated in Table 5.

Table 5 Comparison of PSNR for different datasets

DS		PSNR Metric		
		Watermark Technique		
		DWT	SWT	NSCT
DS-II	LENA	41.3280	44.8833	47.8777
DS-II	BARBARAA	37.2362	39.6533	40.4668
DS-II	SUNIL	41.8023	42.9936	44.9115
DS-I	SATELLITE	34.3759	35.8539	39.3879

a) Analysis of DS dataset

A high value for PSNR is observed for NSCT technique, as shown in Table 5. In other words, NSCT technique is suitable for recovering of watermark images with high PSNR values in comparison to CT, SWT and DWT based de-nosing techniques. Amongst the watermarking techniques, the recovered image generated by DWT technique yields low values of PSNR. This may be due to the sub-sampling effect involved in DWT, leading to the introduction of false information in the resulting recovered image.

A subjective interpretation of PSNR values suggests that NSCT technique using exhibits the highest performance in terms of preservation of colour radiometry and structural similarity information, when compared to CT, SWT and DWT based watermarking techniques. Thus, it can be ascertained that NSCT technique is best in preserving the structural similarity and colour radiometry of the recovered image, when compared to other based watermarking techniques. In other words, NSCT technique emerged as one of the most effective technique, for recovering of watermark images. This is followed by CT, SWT and DWT based DW techniques.

4.2.3 Analysis based on TAF

In general, a low TAF value would indicate that the fused image is more similar to the original image. The results of TAF for different datasets are given in Table 6.

Table 6 TAF values for different Watermarking techniques

DS		TAF Metric		
		Watermark Technique		
		DWT	SWT	NSCT
DS-I	LENA	3.692	3.589	2.698
DS-II	BARBARA	4.715	4.109	4.090
DS-II	SUNIL	2.663	2.659	2.657
DS-I	SATELLIT	3.723	3.702	3.521

From Table 6, it is observed that the value of TAF generated by NSCT based watermarking technique indicates good quality of extracted image, followed by SWT and DWT techniques. Amongst the watermarking techniques, the recovered images generated by DWT technique gives the lowest performance in terms of TAF value. This is an indication of high extent of tampering in terms of spatial and structure similarity of the extracted image, when compared to original image. This may be due to the reason of sub-sampling operation involved in the DWT technique, leading to the introduction of artifacts in the resulting extracted image.

4.2.4 Analysis based on MSSIM

Ideally, the value of MSSIM should be equal to 1. The results of MSSIM for different datasets are given in Table 7.

Table 7 MSSIM values for different Watermarking techniques

DS		MSSIM Metric		
		Watermark Technique		
		DWT	SWT	NSCT
DS-I	LENA	0.902	0.925	0.940
DS-II	BARBARA	0.879	0.889	0.909
DS-III	SUNIL	0.911	0.920	0.944
DS-IV	SATELLITE	0.823	0.906	0.915

A high value for MSSIM is observed for NSCT technique (Table 7). This is an indication of good spectral as well as structural similarity characteristics retain in the recovered image, when compared to the original image. This is closely followed by SWT technique. Further, it is found that DWT yields low values for MSSIM metric. This is due to the sub-sampling effect involved in the DWT technique, which causes artifacts in the resulting extracted image.

V. CONCLUSION

In this study, a comparison of performance of spatial-scale based DW techniques, have been carried out in terms of objective and subjective measures. Analysis of result shows that recovered image by NSCT technique yields the best result in terms of objective and subjective measures. This may be due to the reason that NSCT technique possess the property of shift-invariant and multi-directionality, which in turn avoids the introduction of false information in the extracted image. Thus, it can be concluded from this study that watermark image can be effectively recovered by using multi-directional and shift-invariant NSCT technique, when compared to CT, SWT and DWT based watermarking techniques. The outcome of this study could therefore be utilized for further image processing tasks.

REFERENCES

1. S. G. Mallat and W. L. Hwang, 1992. Singularity detection and processing with wavelets," IEEE Trans. Inform. Theory, 38, 617–643.
2. A.K. Jain, Fundamentals of digital image processing. Prentice-Hall,1989
3. J. Lu, J. B. Weaver, D.M. Healy, and Y. Xu, 1992. Noise reduction with multiscale edge representation and perceptual criteria," in Proc. IEEE-SP Int. Symp. Time- Frequency and Time-Scale Analysis, Victoria, BC, 555–558.
4. Bamberger, R. H., & Smith, M. J. T., 1992. A filter bank for the directional decomposition of images: Theory and design. IEEE Transaction Signal Processing, 40(4), 882–893.
5. Do, M.N. and Vetterli, M., 2005. The contourlet transform: an efficient directional a multi-resolution image representation. *IEEE Transactions on Image Processing*, 14(12), 2091-2106.
6. Cunha, A.L., Zhou, J. and Do, M.N., 2005. Non sub sampled Contourlet Transform: Filter Design and Applications in De-noising. *In IEEE International Conference on Image Processing*, 1, pp. 749-752.
7. Cunha, A.L., Zhou, J. and Do, M.N., 2006. The Non Sub- sampled Contourlet Transform: Theory, Design and Applications. *IEEE Transactions on Image Processing,* 15(10), 3089-3101.
8. Muath Al Shaikh, Lamri Laouamer, Laurent Nana, Anca Pascu, 2016. "A Novel CT Scan Images Watermarking Scheme in DWT Transform Coefficients", IJCSNS International Journal of Computer Science and Network Security, 16(1), 62-71.
9. Li, S., Li, Z. and Gong, J., 2010. Multi-variate statistical analysis of measures for assessing the quality of image fusion. *International Journal of Image and Data Fusion*, 1(1), 47–66.
10. Li, S., Yang, B. and Hu, J., 2011. Performance comparison of different multi-resolution transforms for image fusion. *Information Fusion*, 12(2), 74–84.
11. V. santhi, P, Arulmozhivarman, " Hadamard transform based adaptive visible/invisible watermarking scheme for digital images", journal of information security and applications
12. Ling-Yuan Hsu , Hwai-Tsu Hu, "Blind image watermarking via exploitation of inter-block prediction and visibility threshold in DCT domain", Elsevier, J. Vis. Commun. Image R. 32 (2015) 130–143.
13. Shao-li Jia, "A novel blind color images watermarking based on SVD", Optik 125 (2014) , pp: 2868–2874.
14. Nasrin M. Makbol, Bee Ee Khoo, " A new robust and secure digital image watermarking scheme based on the integer wavelet transform and singular value decomposition", 2014 Published by Elsevier Inc.
15. Schneier, B., 1996. *Applied Cryptography*, 2^{nd} edition, Wiley, New York.
16. Kundur, D. and Hatzinakos, D., 1999. Digital watermarking for telltale tamper proofing and authentication. *In Proceedings of IEEE,* 87(7), pp. 1187-1180.
17. Patra, J.C., Karthik, A. and Bornand, C., 2010. A novel CRT based watermarking technique for authentication of multimedia contents. *Digital Signal Processing*, 20(2), 442–453.
18. Patra, J.C., Phua, J. E. and Bornand, C., 2010. A novel DCT domain CRT-based watermarking scheme for image authentication surviving JPEG compression. *Digital Signal Processing*, 20(2), 442–453.

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