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# Watermarking Scheme based on Redundant Discrete Wavelet Transform, Singular Value Decomposition and Uniform Probability Density Function

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**ABSTRACT**: Now a day's watermarking is one of the major one in the copyright protections and proof of ownership applications in digital image processing. As the technology improves day by day, it becomes a challenging task for the researchers to develop new algorithms under different noise attacks. While embedding a watermark in a host image, security, robustness and imperceptibility are the major factors to be concerned. The proposed method using Uniform Probability Density Function (Uniform PDF), Redundant Discrete Wavelet Transform (RDWT) and Singular Value Decomposition (SVD) i.e. RDWT-SVD-Uniform PDF, achieved a large capacity due to redundancy in RDWT domain and high degree of imperceptibility due to SVD properties. The proposed method shows a significant improvement in terms of Peak signal to Noise Ratio (PSNR) when weighted against existing technique RDWT-SVD.

**KEYWORDS:** *RDWT*, SVD, Uniform PDF, Watermarking.

## I. INTRODUCTION

Recently, the wide increase in the pirated digital media due to the technology enhancement and the ease of distribution, has led to the need to protect the media against attacks [1]. The digital media (such as audio, video, text or image) can be easily modified by the attackers which may lead to claim its ownership.

So it is required to develop robust methods to prevent unauthorized copying and redistributing it on the network become a critical task for the researchers in digital watermarking. Traditional method such as copyright protection and encryption could not solve the problem of unauthorized copying entirely. It is clear from the literature digital watermarking provides a possible solution to the said problem.

Digital watermarking is a technique for inserting information (watermark) into an image, which can be later extracted or detected for variety of purposes, includes the identification and authentication purposes. The watermark embedded may be visible or invisible. The performance of digital watermark can be evaluated based on the parameters like Robustness, perceptual transparency, secrecy, complexicity and capacity.

The digital watermark can be classified into various categories as perceptible and imperceptible, robust and fragile, public and private watermarks. According to the domain these are subdivided as spatial and transform domain techniques. In spatial domain the water mark is directly embedded into the cover image by changing the pixel values of the data, for example watermarking using SVD. In transform domain it is done by altering the transform coefficients for example watermarking using DCT [2] and DFT [3].

The paper is organized as follows. Section 2 deals with related work. Section 3 discusses about the proposed work. Experiment results and discussion is presented in section 4 and conclusion is given in section 5.

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## II. RELATED WORK

### *A. REDUNDANT DISCRETE WAVELET TRANSFORM (RDWT/SWT)*

***Wavelet*** is rapidly decaying wave like oscillation that has zero mean. Unlike sinusoids, which extends to ∞, a wavelet exits only for finite duration. Wavelet may be in different sizes and shapes. The availability of a wide range of wavelets is the key feature of the wavelet analysis. To choose the right wavelet you need to consider the application that you use it for.

The discrete wavelet transform (DWT) [4] is the implementation of the wavelet transform using a discrete set of the wavelet scales and translations obeying some defined rules.

### *B. NEED FOR DISCRETE WAVELET TRANSFORM*

The DWT provides sufficient information both for analysis and synthesis of original signal with a significant reduction in the computation time. The DWT [4] is considerably easier to implement when compared to CWT.

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1. DWT analysis

$$c_j[k] = \left(c_{j+1}[k] * h[-k]\right) \uparrow 2 \;--(1)$$

$$d_j[k] = \left(c_{j+1}[k] * g[-k]\right) \downarrow 2 \;--(2)$$

Where * indicates the convolution and ↓2 indicates the down sampling

i. e. $y[n] = x[2n] \;--(3)$

2. DWT synthesis

$$c_{j+1}[k] = ((c_j[k] \uparrow 2) * h[k] + (d_j[k] \uparrow 2) * g[k]) \;--(4)$$

Where ↑ here denotes to the up sampling process i.e. if $y[n] = x[n] \uparrow 2$ then

$$y[n] = \begin{cases} x\left[\frac{n}{2}\right], n \text{ is even} \\ 0, \quad n \text{ is odd} \end{cases} \;---(5)$$

### *C. ADVANTAGES OF RDWT OVER DWT*

Classical DWT is not a shift invariant. This means that DWT of translated version of a signal $x$ is not the same as the DWT of the original signal. Shift invariance is important in many applications such as pattern detection and de-noising etc. Translation invariance [11] is achieved by removing the down sampling and up sampling in DWT and it is done by using a special algorithm called as Redundant Discrete Wavelet Transform (RDWT) [5] and it is also called as SWT Stationary Wavelet Transform). The SWT is most commonly known as "algorithme a ̀trous" in French (word trous means holes in english) which refers to inserting zeros in the filter.

As shown in fig 2, the RDWT itself removes the up sampling and down sampling coefficients .Therefore the filters themselves are up sampled to suitable length of growing data are as

$$h_j[k] = h_{j+1}[k] \uparrow 2 \;------(6)$$

and $g_j[k] = g_{j+1}[k] \uparrow 2 \;----(7)$

1. RDWT analysis

$$h_j[k] = \left(c_{j+1}[k] * h[-k]\right) \;--(8)$$

$$d_j[k] = \left(c_{j+1}[k] * g[-k]\right) \;--(9)$$

2. RDWT synthesis

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$$c_{j+1}[k] = \frac{1}{2}\left(c_j[k] * h_j[k] + d_j[k] * g_j[k]\right) ----(10)$$

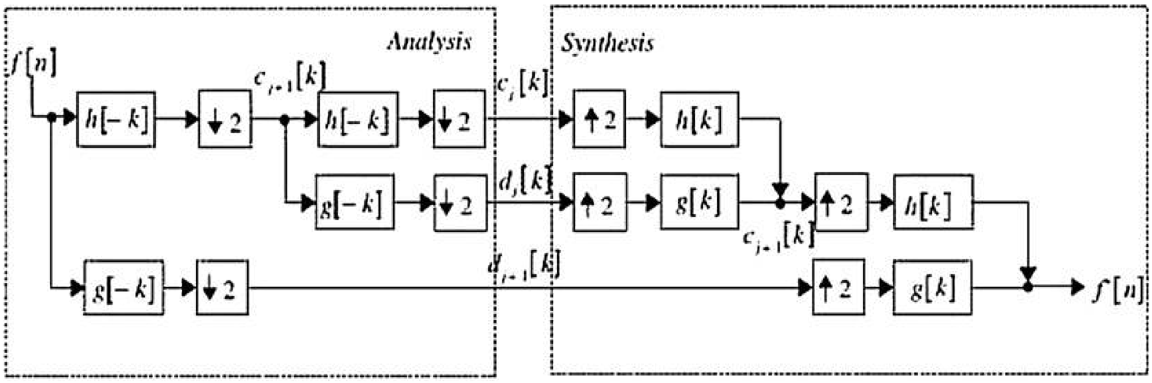


**Figure1. Two level 1D DWT analysis and synthesis filter bank**

***D. SINGULAR VALUE DECOMPOSITION (SVD)***

SVD is a most widely used technique in various applications like image hiding, image compression, Noise reduction and in image water marking.SVD [4], [6] is based on a theorem from linear algebra says that a rectangular matrix A can be broken down into 3 matrices as orthogonal matrix 'U' ,a diagonal matrix 'S' and the transpose of orthogonal matrix 'V'. The theorem is usually presented like this as

$$A = USV^T ----(11)$$

$$s = \begin{matrix} \lambda 1 & 0 & 0 \\ 0 & \lambda 2 & 0 \\ 0 & 0 & \lambda 3 \end{matrix} \quad \text{For } 3\times 3 \text{ size}$$

Where $UU^T = I, VV^T$ =I , the columns of U are orthogonal Eigen vectors of $A$ and the columns of V are orthogonal Eigen vectors of $A$ and S is a diagonal matrix containing the square roots of Eigen values from U and V in descending order, here SVD is used for watermarking embedding process [7],[8],[9].The disadvantage present in the existing RDWT-SVD algorithm is that the scaling factor α is fixed one. So to have better performance in terms of PSNR the proposed RDWT-SVD-Uniform PDF algorithm is used.

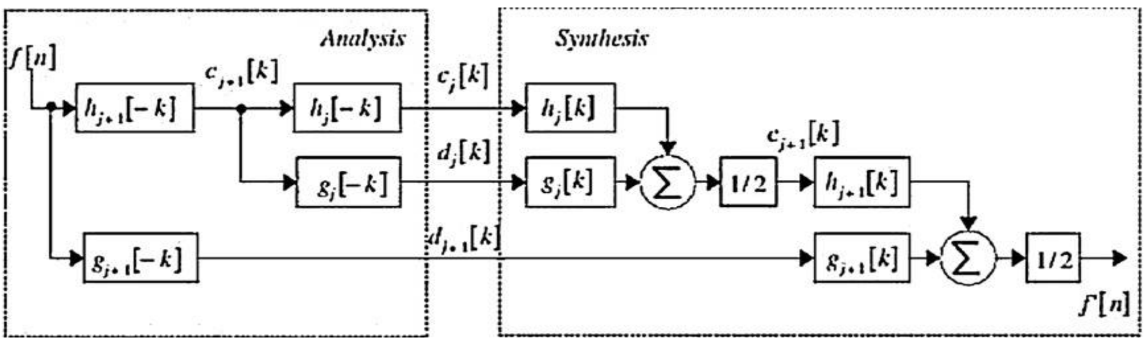


**Figure2. Two level 1D analysis and synthesis filter banks**

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(a) (b) (c) (d)

**Figure 3 (a) Host image (peppers) (b)Watermark image (VVIT) (c)Watermarked image (peppers) (d) Extracted watermark image**

## III. PROPOSED WORK

To overcome the drawback present in the RDWT-SVD algorithm, the uniform probability density function along with RDWT and SVD [5] techniques was used. The Uniform Probability Distribution function is applied on cover image to get the value of '**α**' which is called the scaling factor for watermarking embedding process.

### *A. WATERMARK EMBEDDING ALGORITHM*

The steps are as follows
Perform 1D RDWT on cover image that decomposes into four sub bands as (LL, LH, HL, HH)

- Apply SVD on all sub bands (LL, LH, HL, HH) as
  $A^i = U^i S^i V^{iT}$, where i indicates the sub bands LL, LH, HL, HH
- Get the value of **α** scaling factor for watermarking by applying Uniform PDF on cover image
  $\alpha = uniformpdf(cover\ image)$.
- Apply SVD to the each sub bands as
  $S^i + \alpha w = U\ W^i S^i_W V^{iT}_W$
  Where $i$ indicates the sub bands LL, LH, HL, HH
- Perform the new modified RDWT coefficients for each sub band as
  $A^{inew} = U^i S^i V^{iT}$
  where $i$ indicates the sub bands LL, LH, HL, HH
- Apply inverse RDWT on 4 sub bands to get watermarked image
  $A_w = RDWT^{-1}$

### *B. EXTRACTION ALGORITHM*

- Apply RDWT on watermarked image $A^*_w$ to decompose it into 4 sub bands
- Apply SVD to all sub bands as

$A^{W*} = U^{*i} S^{*i} V^{*iT}$

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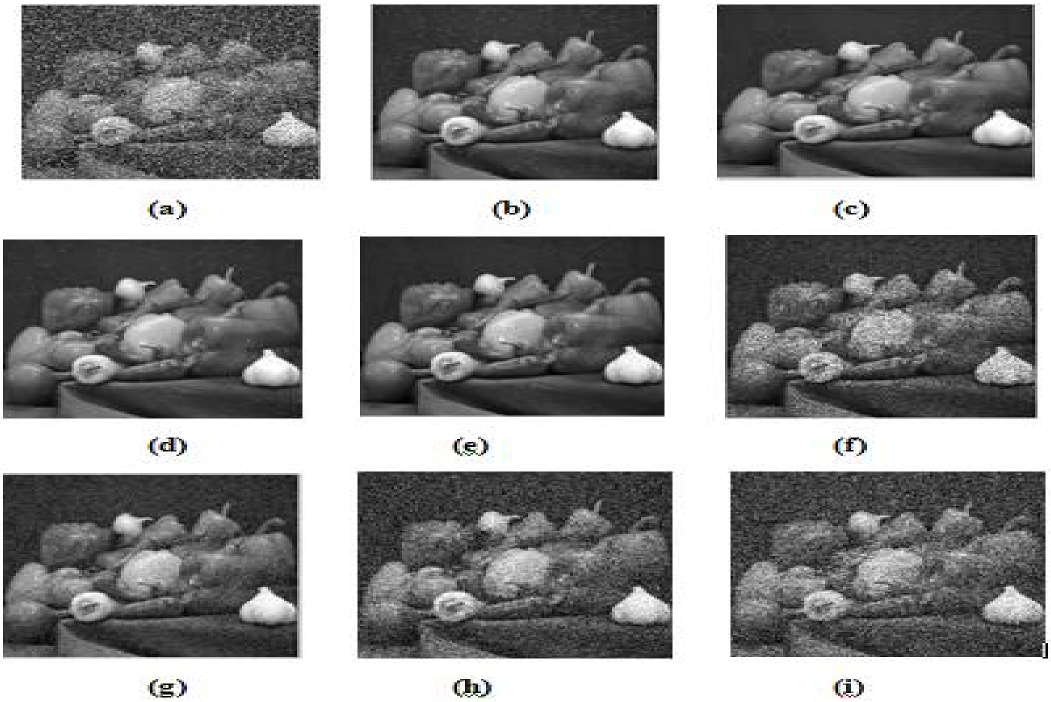


**Figure4(a).Watermarked image under salt and pepper noise (0.3) (PSNR 10.2309); (b).Watermarked image under salt and pepper noise (0.01) (PSNR 25.0773); (c). Watermarked image under salt and pepper noise (0.001)(PSNR 35.2101) ; (d). Watermarked image under salt and pepper noise (0.005) (PSNR 28.4087) ; (e). Watermarked image under speckle noise (0.01)(PSNR 28.8270) ; (f). Watermarked image under speckle noise (0.3)(PSNR 14.5851); (g). Watermarked image under Gaussian noise(0,0.01)(PSNR 20.1826) ; (h).Watermarked image under Gaussian noise(0, 0.05)(PSNR 14.0263) ; (i). Watermarked image under Gaussian noise (0, 0.1) (PSNR 11.6882).**

## IV. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed method is implemented using MATLAB and tested on a cover image of size of 512×512 with a watermark of size 256×256. Here VVIT image is considered as watermark image and it is embedded into the cover image. A Uniform probability distribution function is used on cover image to find the value of α which helps in determining the imperceptibility. The performance of the proposed method is evaluated based on the metrics peak signal-to-noise ratio and Mean Square Error (MSE) to denote the imperceptibility degree.

To test the robustness of the watermarks different noise attacks are simulated. The PSNR can be calculate as follows

$$PSNR = 10 log_{10}\left[\frac{\max(x(i,j))2}{MSE}\right] --(12)$$

Where the mean square error (MSE) between the cover image and $x$ and the watermarked image $y$ is defined as

$$MSE = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n}[x(i,j) - y(i,j)]^2 --(13)$$

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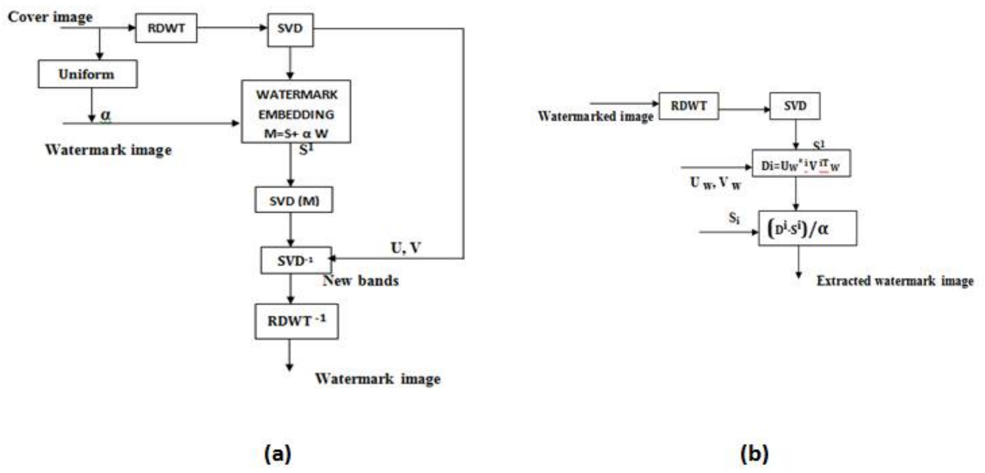


**Figure 5(a)The process of watermark embedding (b) Process of watermark extraction**

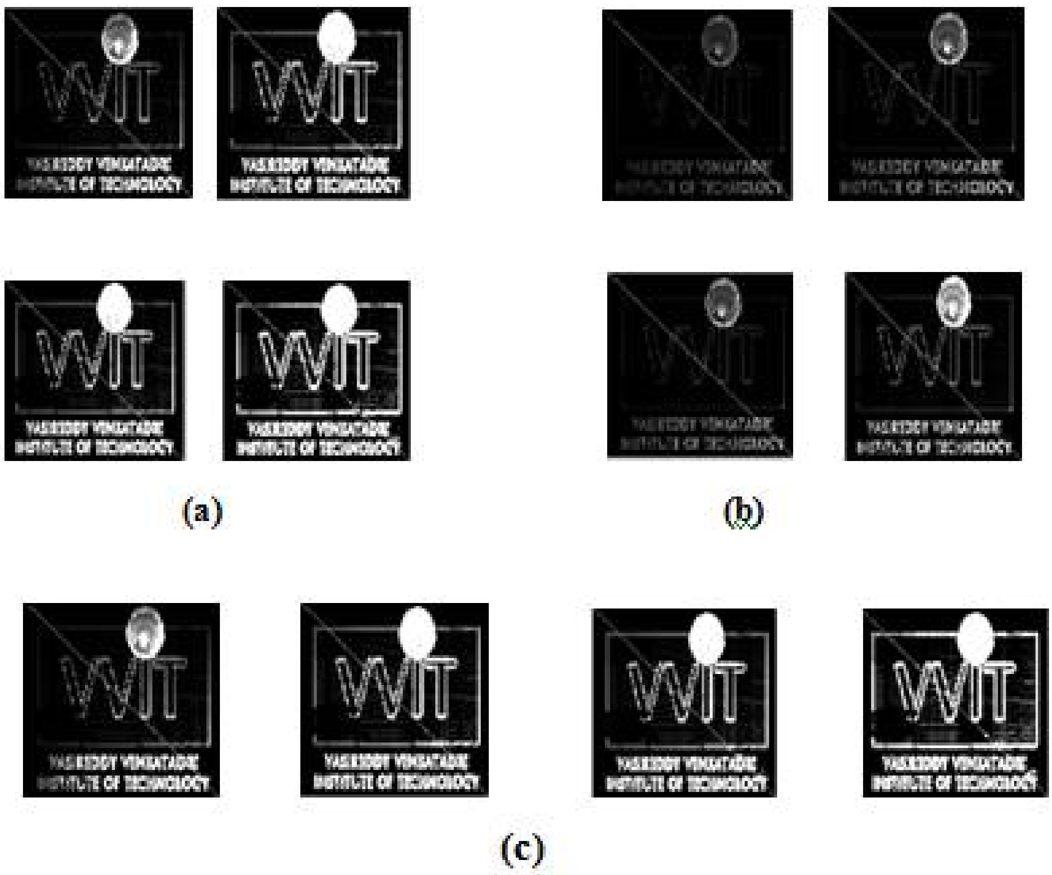


**Figure 6 (a) Extracted watermark after salt & pepper noise(0.3)(PSNR 10.1971db) (b) Extracted watermark after speckle noise(0.01)(PSNR 28.8438 db) (c) Extracted watermark after Gaussian (0,0.5)(PSNR 7.8356 db)**

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**Table 1**
**Comparison of PSNR (db) for our scheme RDWT-SVD-Uniform PDF with RDWT-SVD**

| Watermark image | Proposed Scheme (RDWT-SVD-Uniform PDF) | RDWT-SVD |
|---|---|---|
| Cameraman | 65.4346 db | 52.833 db |
| VVIT | 98.972 db | 81.4654 db |

**Table 2**
**Comparative analysis of RDWT-SVD-Uniform PDF with RDWT-SVD scheme**

| Description | RDWT+SVD | Proposed |
|---|---|---|
| Type of scheme | Blind | Blind |
| Type of transforms | RDWT+SVD | RDWT+ SVD+ Uniform PDF |
| Embedding sub bands | All | All |
| Size of host image | 512×512 | 512×512 |
| Type of watermark | Gray | Gray |
| Scaling factor(α) | 0.05(LL) 0.005(remaining) | Image dependent for proposed Host image α= 0.0045 for all sub bands(LL,LH,HL,HH) |

.

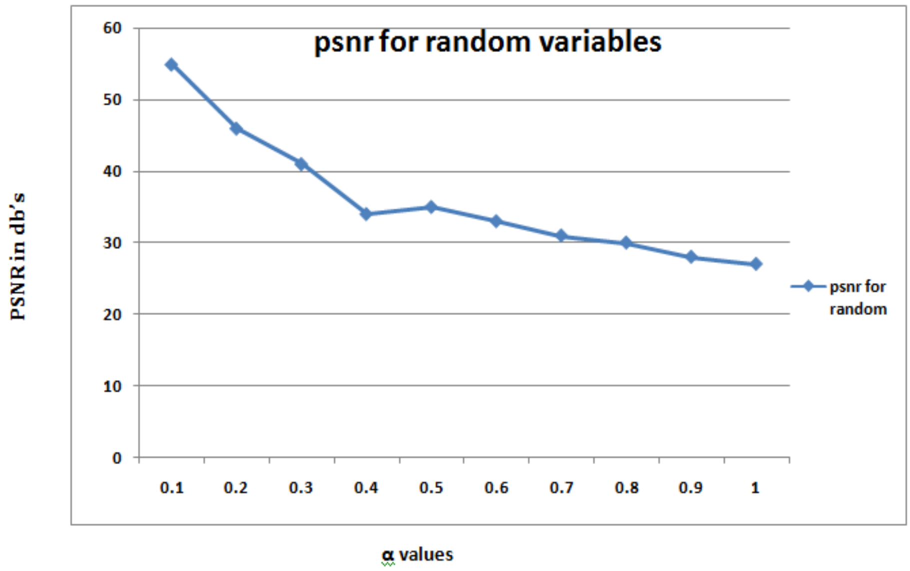


**Figure7. Graphical representation of PSNR Vs α as a random variable within the range of 0 to 1**

## V. CONCLUSION

The watermark is embedded into the host image using the proposed method RDWT-SVD-Uniform PDF. The proposed method RDWT-SVD-Uniform PDF was tested for various values of scaling factor α which gives the most

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possible high PSNR. The Uniform PDF is applied on the image and the watermark was directly embedded to all the RDWT Sub bands. Although embedded data may lead to distorted, the proposed method preserved high degree of imperceptibility and improved PSNR. The experimental results produced in this paper achieved high PSNR under various noise attacks. Thus the proposed scheme satisfied high PSNR, imperceptibility and security requirements.

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