PERCEPTIBLE REVERSIBLE (LOSSLESS OR DISTORTION LESS) COMPANDING TECHNIQUE BASED ON HAAR AND CDF(9/7) WAVELETS

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Abstract: Reversible Data Hiding (RDH) is the data hiding technique that can recover the original cover data from the stego-object (obtained after the secret data is embedded in the cover data) after extracting the embedding data in it. In this paper, we present a perceptible RDH based on Haar Wavelet and CDF(9/7) wavelets using companding technique. The algorithm is implemented on Matlab R2010b. The quality measure (PSNR), Structural Similarity measure (SSIM), Provable Security(KLDiv) and Embedding Capacity are used as performance measures. From the experimental results it is observed that Haar based P-RDH is a better option than CDF (9/7) in terms of quality measure, structural similarity measure and provable security. However, the proposed technique fails to statistical attacks and robustness.

Keywords: P-RDH, Haar Wavelet, CDF (9/7), PSNR, SSIM, KLDiv, Embedding Capacity.

1. **Introduction:** RDH is an effective technique that can reversibly embed secret information into cover data. The property of reversibility means that the original form of the cover data, before the secret bits were embedded, can be recovered completely after the embedded bits are extracted. This technique is useful in many fields such as copy right protection, digital watermark, law enforcement, digital forensic, medical imagery, astronomical research, and content authentication of multimedia data. These fields do not allow any modification in the digital representation of the cover data due to the risk of misinterpretations.

A number of RDH techniques have been proposed. Celik et al. [2] have classified Reversible data embedding techniques into two categories: Type I: Additive spread spectrum techniques [3], and Type II [7]: information bits are embedded by modifying, e.g. overwriting, selected features (portions) of the host signal -for instance least significant bits or high frequency wavelet coefficients where a spread spectrum signal corresponding to the information payload is superimposed on the host in the embedding phase. At the decoder, detection of the embedded information is followed by a restoration step where watermark signal is removed, i.e. subtracted, to restore the original host signal. Potential problems associated with the limited range of values in the digital representation of the host signal, e.g. overflows and underflows during addition and subtraction, are prevented by adopting modulo arithmetic. Payload extraction in Type-I algorithms is robust. On the other hand, modulo arithmetic may cause disturbing salt-and-pepper artifacts.

In Type II algorithms -. Since the embedding function is inherently irreversible, recovery of the original host is achieved by compressing the original features and transmitting the compressed bit-stream as a part of the embedded payload. At the decoder, the embedded payload- including the compressed bit-stream- is extracted, and original host signal is restored by replacing the modified features with the decompressed original features. In general, Type II algorithms do not cause salt-and-pepper artifacts and can facilitate higher embedding capacities, albeit at the loss of the robustness of the first group.

Awrangjeb [1] has classified these techniques under different concepts: 1. Lossless compression and encryption of Bit- planes, 2. Reversible data hiding at Low Pixel-levels, 3. Circular interpretation of Bijective Transformations based on integer Wavelet transform, 4. Capacity based on difference expansion and 5. RDH by histogram shifting.

According to X. Zhang [15], they can be classified into three types, viz., 1. Lossless compression based methods, 2. Difference expansion (DE) and 3. Histogram modification (HM) methods.

In 2012, Yang, Lin and Hu [14] , defined the two kinds of RDH schemes: 1. ***Perceptual quality schemes*** that provide a perceived high quality in stego-images with a high embedding rate and, 2. ***Robustness-oriented schemes*** which are robust to image processing operations.

The performance evaluations for RDH, i.e., *the hiding capacity* and *the quality* of stego-data, have been investigated by researchers using different techniques. Some applications, especially the 'Digital Forensics' is very promising. The objective of this paper is to gather high quality research efforts that address the challenges of the emerging area of RDH for digital forensics with a view to provide the researchers with an overview of the state of the art in this field.

Kumar S. and Muttoo SK [4] proposed a distortionless data hiding technique based on discrete slantlet transform. They have observed that SLT is a better option than DWT in terms of image quality.

Muttoo and Kumar [3] extended their work to complex wavelet transform and used AED an an integral part of steganographic system for better confidentiality and security. They have shown that DD DT DWT is a better option than DWT for secure, robuts and high embedding capacity image steganography method.

Kumar S [4] presented a Secure (multi-layered security), robust, high embedding and efficient RDH scheme based on SLT using self-synchronizing variable length codes: T-codes [6,7] and AES method, respectively

In this paper we shall study of the perceptible reversible image steganography scheme based on Haar wavelet using companding technique. The self-synchronizing variable length codes: T-codes are used for encoding the message at pre-processing stage.

2. Review of Companding technique

In this section we briefly summarize one of the companding technique, known as thresholding technique

A reversible (or Lossless) steganographic algorithm based on thresholding technique proposed by Xuan G. et al. [9, 10].

In the thresholding embedding, a threshold value *T* is predefined. To embed data into a high frequency coefficient x, the absolute value of the coefficient is compared with T. If |x| < T, the coefficient value is doubled and the new LSB is replaced with an information bit. The resultant coefficient is denoted by x′. Otherwise, if x ≤ T, the coefficient will be added by T, if x ≥ -T, the coefficient will be subtracted by (T-1) and no bit is embedded into this coefficient.

In the data extraction stage, if the coefficient x is less than 2T and larger than (-2T+1), the LSB of this coefficient is the bit embedded into this coefficient. Otherwise, we jump to the next coefficient since the current coefficient has no hidden bit in it. Besides hidden data extraction, the original cover image is also recovered.

The process of embedding and extraction of thresholding technique is shown in Table 1. Here, b is the message bit, x is the high frequency coefficient and x' is the corresponding modified frequency coefficients.

Table 1. Threshold method *(COMPANDING TECHNIQUE):*(Predefine a threshold value, T)

Embedding	Extraction
$x' = \begin{cases} 2*x + b & \text{if } \lvert x \rvert < T \\ x + T & \text{if } x \geq T \\ x - (T-1) & \text{if } x \leq -T \end{cases}$	$x = \begin{cases} \lfloor x'/2 \rfloor & \text{if } -2T < x' < 2T \\ x' - T & \text{if } x' \geq 2T \\ x' + T - 1 & \text{if } x' \leq -2T+1 \end{cases}$

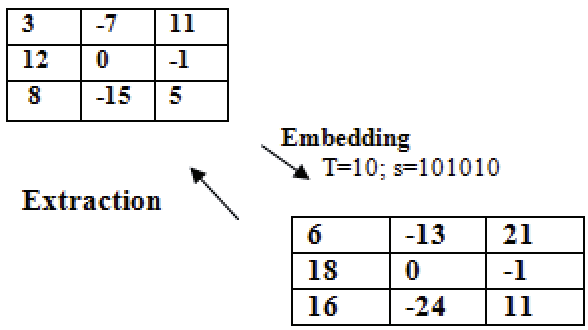

Fig.1. Illustration of Companding Technique

3. **Proposed algorithm :** The proposed embedding and extraction algorithms based on Haar Wavelet transform are summarized below:

Algo 3.1: Embedding:

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Step 1: *Obtain the secret binary message from the original embedding message by/ applying a self-synchronizing variable length codes, T-codes.This also generates an encoding-key, K.*

Step 2: *Perform the histogram modifications to the cover image to prevent overflow/underflow.*

Step 3: *Obtain the four frequency subbands LL, LH, HL and HH on apply the 2D Haar/CDF(9/7) wavelet transform to the cover image.*

Step 4: *The frequency coefficients of middle and high sub-bands, HH, HL and LH obtained through Haar/CDF9/7 are converted into integer values using threshold T=1.*
Step5. *Permute the coefficients of sub-bands, HL, LH and HH randomly using a random-key, k and obtain new sub-bands LH', HL' and HH'.*
Step 6: *Embed the secret binary message into the corresponding randomly chosen Coefficients of middle and high sub-bands using the thresholding technique.*
Step7. *Restore the coefficients of subbands on applying the inverse of the random Permutation used in step 5.*
Step 8. *Obtain the stego- image by taking the inverse Haar/CDF9/7 transform of the modified image obtained by merging the middle and high sub-bands with low sub-band LL*
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Random selection of coefficients in Step 5 provides more security where the sequence of the message is only known to both sender and receiver by using a previously agreed upon secret key.

Algo 3.2: Extraction

This is just reverse of the embedding algorithm and is given as follows:

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Step1. *Obtain the middle and high frequency subbands from the stego-image by applying 2-level Haar/CDF(9/70 wavelet transform.*
Step2. *Permute the coefficients of middle and high frequency subbands, HL, LH and HH using the permuting key, used in step 5 of embedding.*
Step3. *Extract secret binary data from the selected frequency coefficients of sub-bands using the stego-key and the reversible thresholding technique.*
Step3. *Obtain the original message by decoding the secret binary data using the encoding key, K.*
Step4. *Recover/Restore the original image by applying reverse operation of the Embedding, that is, removing the secret data embedded from the selected coefficients*
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4. Experimental results: In this section we shall present the analysis of the proposed algorithm. The performance of the algorithm will be measured in terms of image quality, strtuctural similarity, and provable security. The execution of proposed algorithm is done on number of images and image formats. For this, we have used 256 x 256 grayscale scale images. Simulation is done using MATLAB R22010b. A comparative study is presented of the proposed algorithm based on Haar Wavelet transform and CDF9/7 wavelets.

4.1 Imperceptiblilty: Table 1 shows the results of the PSNR values obtained on implementing the proposed algorithm for some of the tested image formats. The Fig. 4.1 shows the results of PSNR for the embedding capacity = 2000 bytes. It is observed that Haar based thresholding method performs better than the CDF9/7 in terms of PSNR, irrespective of image formats.

Table 4.1: PSNR values for RDH Algo 3.1 based on Haar and CDF9/7

Image	HAAR (6000 bytes)	CDF9/7 (6000 bytes)	HAAR (2000 bytes)	CDF9/7 (2000 bytes)
C3.jpg	28.747012	26.78702	32.74543	27.74672
Tulips.jpg	28.775221	24.340296	36.32557	24.823396
New7.tif	28.730439	24.565361	38.48209	25.993797
New8.tif	27.852301	20.133592	29.70768	21.746396
New11.tif	28.305625	22.484001	37.10401	24.131382
New12.tif	28.671414	25.151761	34.43308	26.774769
Baboo.bmp	23.996821	19.757215	27.38116	21.856399
C2.bmp	28.808651	28.750585	37.39504	30.791012
Zoneplate.png	13.869799	7.814199	18.93664	8.671013
Tooth1.jpg	29.021136	30.988604	39.24182	33.829992
Peppers.png	28.750906	27.63027	36.13998	28.842123
C1.png	28.737853	30.104708	32.95031	31.545956

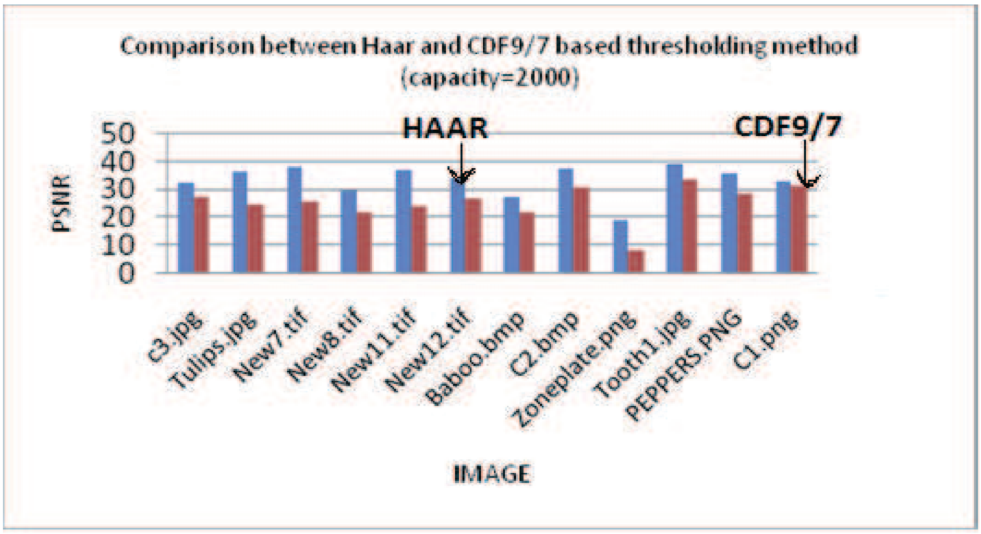

Figure 4.1: PSNR values of different images based on Haar and CDF9/7 reversible thresholding method for Algo 3.1 with embedding capacity= 2000 bytes

4.2 Structural similarity: The results of SSIM obtained on implementing the proposed algorithm Algo 3.1, for some of the tested images from the tested database of images are shown Fig. 4.3. . It is observed that Haar transform based P-RDH provides better structural similarity of image than the CDF9/7 based P-RDH method.

It is noted that in the case of Haar based P-RDH method all the images have their SSIM values close to each other (lines are seen to be overlapping) whereas it is seen that there is a variation in the values of SSIM for tested images for CDF9/7 based proposed P-RDH method. One may conclude that CDF9/7 based proposed method depends on the intrinsic property of images whereas Haar based proposed method shows tolerance to the intrinsic property of images.

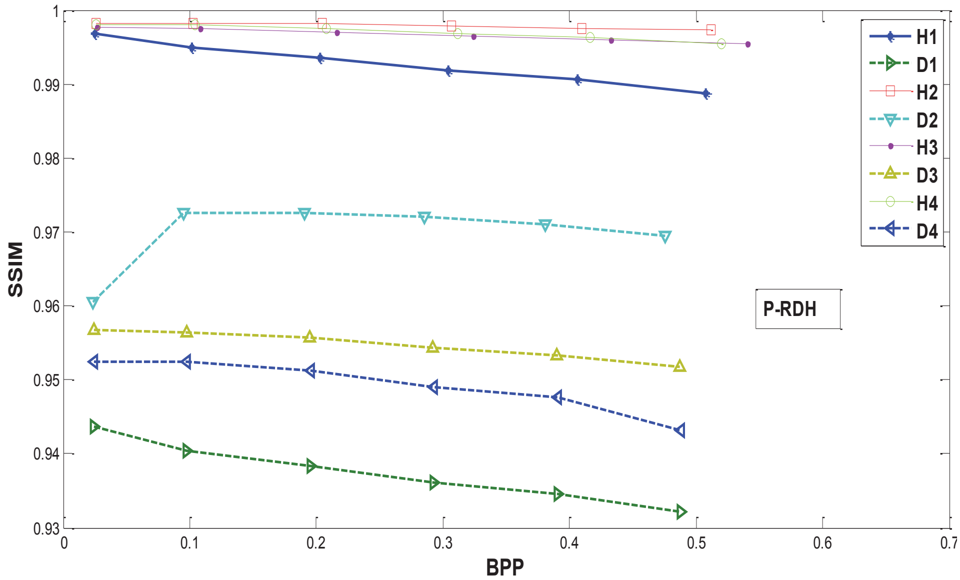

Figure 4.3: The comparison between Haar & CDF9/7 in terms of SIMM for Algo 3.1 with threshold =35 (H1 & D1 refer to 'C1.png'; H2& D2 refer to 'C2.bmp'; H3 & D3 refer to 'C3.jpg' and H4 & D4 refer to 'New12.tif')

4.3 Provable security: The maximum values of KLDiv for some of the tested images for the proposed Algorithm are shown in Fig. 4.4. It is observed that Haar transform shows provable security (KLDIv ~ 0) whereas CDF9/7 lacks provable security.

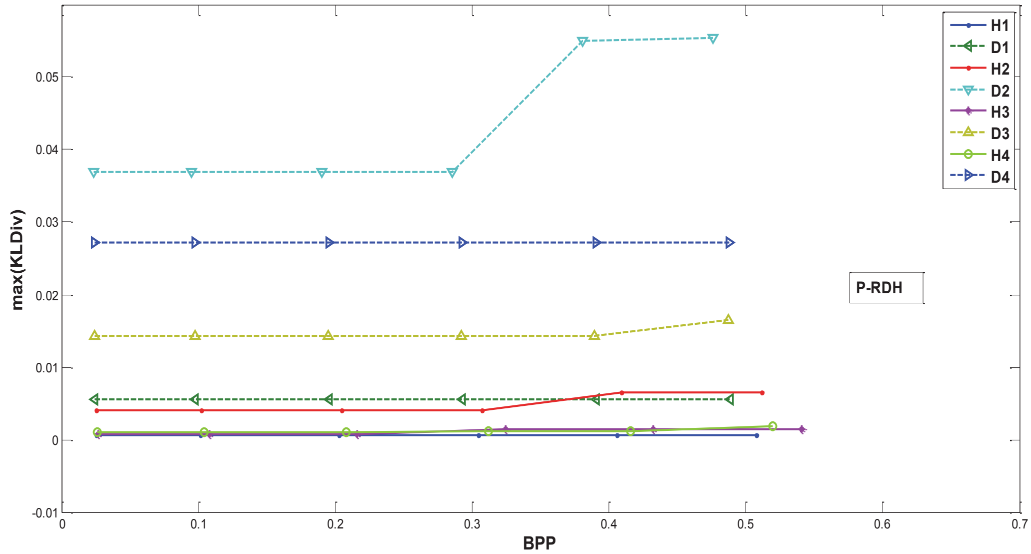

Figure 4.4: KLDiv vs BPP for Algo 3.1 with threshold=35

Finally, it can be seen from Fig.4.5 where the results of the recovered image is shown for one of the tested image that original is restored after the embedded message is removed from the stego-image.

Figure 4.5: Recovered image from Algo 3.1 based CDF9/7 with secret message=689 bits, threshold=35, T= 6.2413

4.4 **Embedding Capacity:** It is noted that as the threshold value T increases, the payload increases but the PSNR decreases. The large threshold value means the strong embedding strength. Thus, the payload and PSNR are contending one another and the embedding strength heavily influences these two parameters. For computing threshold, we use the spatial context information of noisy image. Noise parameter estimated from the noise content through median absolute deviation (MAD) estimation, i.e., σ_n^2 = median ($|y_i|$) / 0.6745, $y_i \in$ subband, and the threshold obtained as T= σ_n^2 / σ_x, x is the subband.

Conclusion: We have presented a perceptible reversible data hiding technique based on Haar and CDF 9/7 wavelet transforms using the companding technique. It is found through experimental results the proposed algorithm based on Haar wavelet transform performs better in terms of image quality, structural similariy and provable security. To increase the embedding capacity we have suggested the optimal threshold value, T= σ_n^2 / σ_x. Table 2 summarizes the comparison results.

Table2. P-RDH and R-RDH based on WLT and SLT

Attributes	CDF9/7 and Haar (P-RDH)
Imperceptibilty	Haar shows Improvement over CDF9/7
Structural Similarity	Nearly perfect in case of Haar and satisfactory for CDF9/7
Provable Secuirty	No for CDF9/7, Yes for Haar
Security against statistical Attacks	Poor
Robusness	Poor

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