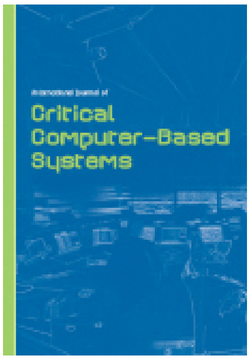

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An enhanced digital image watermarking technique using DWT-HD-SVD and deep convolutional neural network

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An enhanced digital image watermarking technique using DWT-HD-SVD and deep convolutional neural network

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Abstract: This paper proposes a novel image watermarking model, which combines discrete wavelet transform (DWT), Hessenberg decomposition (HD), singular value decomposition (SVD)-based deep convolutional neural networks (D-CNN) technique to explore the subjective and objective quality of the images. Initially, the source and cover image are preprocessed using random sampling techniques. During the process of embedding a watermark image, the cover image is decomposed into a number of sub-bands using the DWT process and the resulting coefficients are fed into the HD process. In continuation to it, the source image is operated on the SVD simultaneously and finally, the cover image is embedded into the source image by the attack-defending process. The probability of data loss during the watermarking extraction process and this issue is postulated by the D-CNN technique that explores the denoising process on the extracted watermarked images. The experimental results show that the proposed method has a good trade-off between robustness and invisibility even for the watermarks with multiple sizes.

Keywords: watermarking; discrete wavelet transform; DWT; singular value decomposition; SVD; deep convolutional neural networks; D-CNN; watermarking embedding; extraction process.

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1 Introduction

Recently, innovations made in digital technologies have revolutionised image processing (IP) fields. Digital images are becoming more eminent in today's environment. Several forms of information such as text, video, audio, images are being transferred via the public channel. Overall, image-based information is receiving more attention among the researchers. Compared to the text, the extraction of information from the images is intuitive and conveyed in a formal way. Irrespective of these benefits, security becomes a major concern in this study (Tsougenis et al., 2014). The evolution of digital technology has gained an interest in the development of digital media-based applications. A tremendous amount of images are being circulated on the web via different sources. Since it is open-source, the images are being easily modified. Recent past techniques, the watermarking process that is employed to protect the information and also preserve the quality of the images. It offers many benefits over analogue media such as audio quality, signals quality etc, of a digital media. Image editing process becomes quite easy where the locations of images are easily modified. In some cases, copying of data is also becoming simpler with no loss of quality. One of the approaches to protect the digital media against the illegal activities are the digital signatures (or) copyright label (or) watermark (Rai and Goyal, 2022).

In order to create a reputation and escape violence, the information should be given through security techniques that should be possible for sound information. When compared to the traditional image processing and data mining, the image mining is quite different (Agarwal et al., 2019; Abdullatif et al., 2013; Su et al., 2012). There is a false belief that the working of image mining and the pattern recognition are similar in process. In real facts, the pattern in the recognition model concentrates on specific patterns whereas image mining focuses on all important patterns. The patterns belong to a single-label classification, but the image mining deals with both single and multi-label classification (Su et al., 2012). An efficient mining system deals with the features related to storage, processing, extraction, indexing, retrieval and patterns. The training features are referred to as patterns. The unlabeled data are matched with pattern and thus, the class of the objects is done. Henceforth, feature optimisation tasks are one of the core components in this study (Rai et al., 2019, 2021).

The development of rapid PC systems and the World Wide Web (WWW) investigated methods for new market, rational, diversion and social open doors such as electronic distribution and advertisement, rubbing, continuous data transmission, knowledge sharing, exchange requests, digital stores and libraries, web papers and magazines, video and sound arrangements (Prathap et al., 2014; Hurrah et al., 2017; Sadreazami et al., 2015). Regardless of the increase in creativity, the cost viability of selling virtual goods as computerised images and video arrangements via transmission over WWW has increased extraordinarily. We know that one of the biggest revolutionary occasions of the last two decades has been the penetration of computerised media into a whole range of normal everyday angles of life. The analysis of digital data is operated at high quality, and thus, PCs can be easily managed using it as well. In addition, digital information (Luo et al., 2018) can be transmitted quickly and cost-effectively via information correspondence systems, without losing quality. Advanced media provides a few preferences in particular over basic media. Digital speech, pictures, and video signals are of a higher quality than their simple partners. Change is easy because one can get to the specific discrete places that should be modified. Duplicating is necessary without any loyalty misfortunes (Haghighi et al., 2018).

The novelties of this paper are:

a the visual quality of watermarked images using DWT-HD-SVD is improved by measuring he two performance metrics, named peak signal to noise ratio (PSNR) and structural similarity index metric (SSIM) are studied.

b different image processing attacks are implemented and tested to prove the efficiency of the algorithms

c compared to prior works, the deployment of filtering, scaling, Gaussian, JPEG compression, rotation and cropping has given satisfactory results

d in this proposed work, the watermark is embedded into LL sub-bands that helps to achieve better PSNR and SNR values during before and after attacks

e the proposed method is more robust than the conventional methods due to the spatial domain improvements

f the proposed techniques have shown 20% increased improvement than existing techniques in terms of PSNR and NC coefficients.

The paper is arranged as follows: Section 2 presents the literature review, Section 3 the research methodology; Section 4 dictates the results and discussion and Section 5 presents the conclusion.

2 Related work

Here, the review of existing studies from the aspects of objectives, techniques designed, merits and demerits are illustrated. In Hurrah et al. (2019), they explored a delicate and blind double watermarking technique for altered identification and self-recovery. In light of the lifting wavelet and the half toning technique, this strategy produces two image digests from the host frame. In this way, for every 22 non-covering squares, two possibilities for recuperating altered squares is given. A visually impaired double watermarking device using DWT, DCT, Arnold adjustment and a novel encryption calculation was discussed in Lee et al. (2019) for safety assurance and content testing of sight and sound data. The discrete cosine transform (DCT) is kept away from the blocking impacts that most watermarking plans usually suffer. An advanced watermarking strategy Li et al. (2018) was developed for 2D and 3D images irrespective of the surface and size. First, the proposed plot provides an unusual guide, called the depth variety projection map (DVPM), to discover areas that are shielded from change in perspective. In addition, a 3-stage Mallat-tree 2-dimensional discrete wavelet transition (2D DWT) were studied to differentiate the three different sub bands sifted on a stage plane, low-pass and vertically high-pass are used as watermarks installing image locales, related to the DVPM. Giri et al. (2015) have introduced a novel calculation using neural synergetic. The calculation first processes a significant dim watermark image, at which point it is inserted into the square discrete cosine transform (DCT) segment as a watermark signal. The streamlining of various watermarking systems using hereditary calculations has been introduced in Li et al. (2018). The insertion and extraction method makes use of the multi-goal wavelet shift investigation and particular decay value. The exploratory result shows that when compared, the different watermarking systems gain more strength, as well as the single watermarking process. The PSNR quality of the watermarked image was administered.

In Mohananthini and Yamuna (2016), they have explored the features of the wavelet coefficients for blinding-based watermarking in sound recordings. Upon the use of 3-level lifting wavelet transformation (LWT), the double implantation is done by outline principle in the low-recurrence estimation sub band on a casing. In addition, the proposed LWT-SSR plot is fused with an improved synchronisation procedure for the following edge areas to adapt to time-moving or potentially time-scaling attacks. In Huynh-The et al. (2018), the authors have presented a visually impaired advanced watermarking plan with two distinctive AI approaches KELM and RKELM dependent on SVD in the IWT area. The KELM and RKELM are the two varieties of ELM in which loads are randomly selected. First the image is modified by IWT to get four sub-groups and then the sub-band HL is selected to separate it into squares and to get the unique values where the real watermark is to be inserted. In Agarwal et al. (2019), the authors have presented the best in class by proposing an image watermarking strategy that endeavours to show the assaults like trimming, scaling and turn as far as the geometrical properties. The addition of the watermark is often efficiently done to provide protection against image handling assaults. Visually impaired and key-based, the watermark position approach often does not allow the first spread research for watermark extraction.

In Zheng et al. (2018), the authors proposed a watermarking scheme reliant on heart disease extraction using double tree complex dimensional subspace for greyscale pictures. First, the disintegration of the host picture is performed utilising DTCWT where huge scope highlights have low recurrence coefficient. Additionally, the highlights are dissected using the score grid acquired from the principal component analysis (PCA). Particular qualities from the score network are then acquired in a lower dimensional subspace using the singular value decomposition (SVD). In Yadav and Singh (2015), they have presented a fragile colour watermarking algorithm, named, Karhunen-Loève transform (KLT) coefficients that embeds the watermarks image. Relying on it, the secret key for the watermark image retrieval process was done. The watermark bits maybe embedded with various methods, particularly the use of syndrome coding has proved versatile and effective. In Koley (2019), the author has presented a novel joint encryption and compression (JEC) technique. It is mainly employed to assess biometric data. The method offers advantages such as reduced data processing, authentication and upgrade acknowledgement accuracy. The biometric information protection is rebuffed by watermarking methods followed by arbitrary component rearrangement. The process of watermarking includes embedding one's unique mark data on his/her compacted face image.

Moreover, an audacity-based watermarking program to ensure copyright protection focused on quaternion-type minutes. Visual cryptography recognises encryption of organised data as a safe way to enable mystery sharing of images and the unscrambling is done through human visual systems. The proposed plot speaks in a quaternion lattice to the shading image, so it can handle the multichannel data in an all-encompassing manner (Ali et al., 2016). In Lusson et al. (2013), the authors developed a tough and blind dual watermarking method to detect tamper and self-recovery models using LSB techniques. A value greater than 46 dB and 44 dB is obtained from the PSNR of the watermark images. It provides high quality image and rate capability In Ahmadi et al. (2020), ReDMark techniques were introduced to diffuse the watermark system. The entire network stimulates the network layer by relatively adjusting the security models. The superior performance is observed in terms of speed and scalability. A CNN-based watermarking technique (Li et al., 2019) was studied to assure a security model for smart city applications In Singh et al. (2018a), multiple watermarking techniques were introduced for online social network contents. The combination of HD, DCT and SVD were introduced to support the low -frequency bands. With the help of back propagation neural network (BPNN), security of the watermarked images is to reduce the distortion effects of the watermarked image. The attacks were not refined by the time-based watermarking modules (Abdelhakim and Abdelhakim, 2018). The performance of the study is done by using meta-heuristic and regression tasks.

3 Research methodology

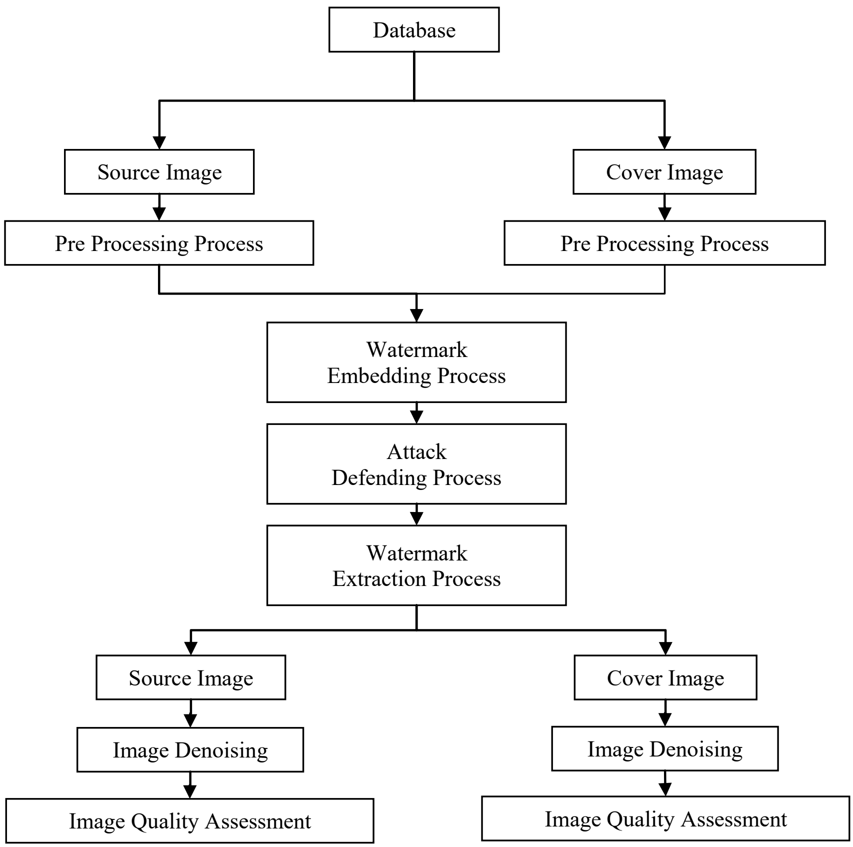
This section presents the proposed feature optimisation models. The objectives of this proposed method are:

- to minimise the trade-off between robustness and invisibility under different sizes of watermark images on different attacks
- to compute, verify and implement the different attacks so as to enhance bandwidth requirements and also minimise storage constraints
- the combination of DWT and SVD into the HD process has improved the visual quality by reducing the distortion rate

- the proposed image watermarking method analysed all attack types and the efficiency of information retrieval from the concealed watermark have also been studied.

To begin the study, the raw image information is collected from the public repository. The collected data are pre-processed and reframed into the execution instruction. Figure 1 shows the proposed workflow whose steps are discussed in the following of this section.

Figure 1 Proposed workflow



3.1 Image pre-processing process

Image pre-processing is the first step of the proposed study. The collected images are pre-processed using sampling techniques. The collected images are subjected to irrelevant noises which are pre-processed using simple random sampling and the grey conversion scale modelling. Initially, the image I is denoted by objects as, $X \in R_N$. The value of the pixel is at location $r \in \partial$ for each object X_r, where ∂ is the location of the pixels. Pixels are arranged in matrix, as:

$$Y^{(k)} = \begin{bmatrix} s^{(1)}, X_{s^{(1)}} \\ \vdots \\ s^{(k)}, X_{s^{(k)}} \end{bmatrix} \tag{1}$$

The above matrix is consecutively performed until all the pixel values are sampled. The X-values are re-arranged according to the arrival of new pixels. The new pixel is located as $\underline{X}^{(k,s)}$. Once the random sampling is done, then the greyscale conversion is performed.

3.2 Image watermarking embedding process

Here, DWT-HD-SVD is employed in this study. The concept of multi-resolution discrete wavelet transform (DWT) with time-scale signal has improved the performance of watermarking under robustness attacks. Along with that, Hessenberg decomposition (HD) behaves in matrix transform which further helps to improve the performance of robustness. Finally, singular value decomposition (SVD) has been introduced to defend against geometric-based attacks.

3.2.1 Discrete wavelet transform

DWT has numerous mathematical operators to resolve the issues pertaining in image analytics. It supports energy representation of an image as well as positively influences the resistivity of an image during the watermarking process. The source image is transformed into four sub-bands that includes low-high (LH), high-low (HL), high-high (HH) and low-low (LL). The image information is obtained from the LL band. The theory of wavelet is to perform on the decomposition until the required watermark data. The characteristics of attacks are more suitable to select the LL bands for the watermarking process.

3.2.2 Hessenberg decomposition

HD is a sort of matrix decomposition model that can be used to project in a square matrix model. Let $n * n$ be the square matrix M which is decomposed using HD, expressed as,

$$OHO^T = HD(M) \tag{2}$$

where

O is the orthogonal matrix

H is the upper bound of Hessenberg matrix.

In the upper Hessenberg matrix, $h_{i,j} = 0$, when $i > j + 1$ and thus, HD is estimated from the householder matrix Q which is expressed as,

$$Q = \frac{\left(I_n - 2\gamma\gamma^T\right)}{\gamma^T \gamma} \tag{3}$$

where γ is the non-zero vector and I_n is the identity matrix. Henceforth, the proposed HD is computed as,

$$O = (Q_1 Q_2 \ldots Q_{n-2})^T O (Q_1 Q_2 \ldots Q_{n-2}) \tag{4}$$

$$H = O^T XO \tag{5}$$

$$X = OHO^T \tag{6}$$

Finally, the robustness is enhanced by finding out the most precise component of the cover image using HD.

3.2.3 Singular value decomposition

SVD is explored in a symmetric matrix including three sub-matrices wherein the singular values are shown up in diagonal matrix form. The three-diagonal matrix form contains the left singular matrix L, singular matrix S and the right singular matrix R. Let A be the symmetric matrix, then SVD is computed as,

$$LSR^T = SVD(A) \tag{7}$$

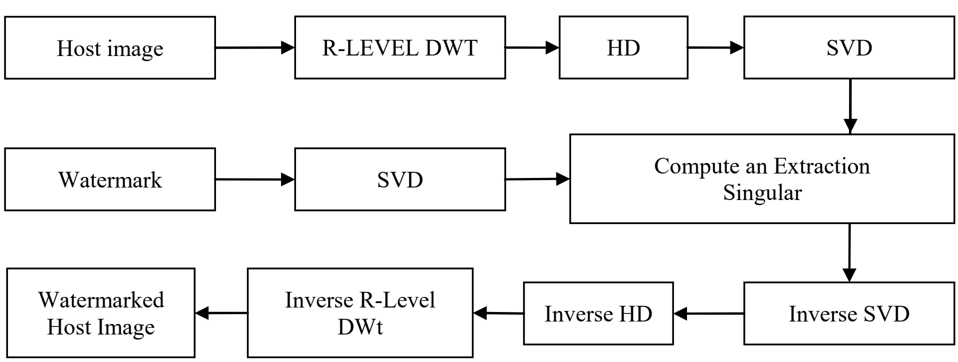
where

$$\mathrm{L}L^T = I_n \tag{8}$$

$$\mathrm{R}R^T = I_n \tag{9}$$

The columns of L are the eigenvectors of $\mathrm{L}L^T$ and the columns of R is the eigenvectors of $\mathrm{R}R^T$ and S is the diagonal matrix that holds square roots of eigenvalues from L and R. The singular value S of SVD is used to embed the cover image under the fittest scaling operator. In some cases, the chance of unfittest scaling factor might affect the invisibility and robustness of the watermarking process. Thus, this trade-off is sorted out by experimenting with the scaling and rotating attacks. These scaling factors are tested and detailed in the experimental section.

Figure 2 Watermarking embedding process



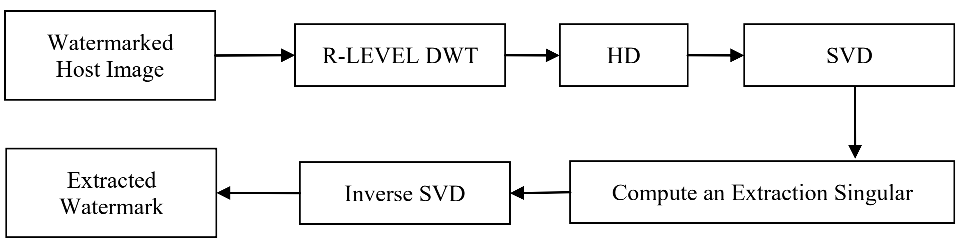
Source: Liu et al. (2019)

With the help of multi-level DWT, the decomposition of host images is done. Then, the resulting coefficient is given as the input for HD in the embedding process. Concurrently, the watermark is applied to the SVD process. The scale factor finally embeds the watermarked to the selected host image. The LL band is considered, since the host image information is at the DWT procedure. By doing so, the robustness i.e. NC analysis is enhanced in the host image of the HD process.

3.3 Image watermarking extraction process

Once the watermarking embedding and the attack-module are performed, the required information is obtained from the watermarking procedures. Here, the input taken is a watermarked image and the output is the extracted image i.e. source image. The role of inverse DWT-HD-SVD is done into four sub-bands by performing R-level DWT. Then, the LL sub band is analysed by HD. Overall, the watermarked output images are then fed into the operators of SVD so as to yield the singular value. At last, the source image is obtained from the output of the SVDs.

Figure 3 Watermarking extraction process



Source: Liu et al. (2019)

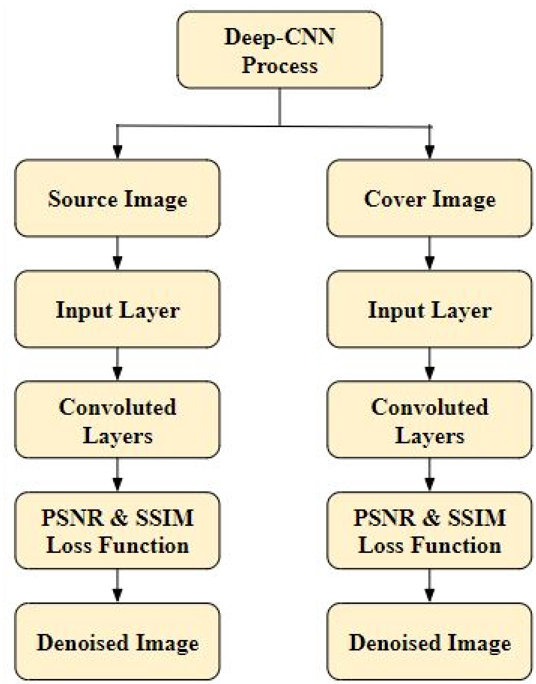
3.4 Image denoising process

One of the important property for performing denoising is to eliminate the noise completely in order to preserve the edges. In this study, several types of attacks are evaluated based on the altered image and the edge preservation attribute and quality of image are accessed. The attacks are analysed using a deep convolutional neural network (D-CNN). D-CNN is fundamentally utilised in the convolution of images with kernels for obtaining a feature map. The weight of the kernel connects the feature map with the previous layers of CNN model and thereby helps in training the model to enhance the input characteristics. The training weights within the convolutional layers are lesser compared to fully connected layers since the kernels for each unit is different. Feature vectors of each de-watermarked image will be fed to CNN. The functionality of CNN can be described in four ways:

- The segmented feature vectors i.e., spatial domains are fed as input to the CNN layer.
- The output of the neurons transfers the input local data by estimating the scalar products over the segmented regions. The weights of the neurons are defined by the dense convolutional layer.

- The pooling layer down sample the inputs based on the parameters achieved on that activation function.
- Denoising is performed in the fully connected layer by using the estimated set of class scores. In this proposed work, the noise is removed by using a watermarking process. It does not distort the denoising procedure. The residual learning strategy of the DCNN can improve the learning process of residual images. The role of residual images is to differentiate the captured information between source image and watermarked image. DCNN is used as image denoising process which has effectively sorted out the data collision and also assisted in improving the effectiveness. The loss function of PSNR and SSIM values are evaluated using the consecutive set of input from the hidden layers and output layers. In DCNN, each layer consists of two set of neurons that would enhance the quality of the pixels.

Figure 4 Workflow of DCNN (see online version for colours)



4 Experimental results

This section elaborates on the simulation setup and the performance measures used to prove the efficacy of the proposed framework. The robustness of the proposed technique is examined in this study. To begin the study, an adaptive scaling factor with different sizes is gathered and explored using normalised correlation (NCs), peak to signal noise ratio (PSNR) and structural similarity index measure (SSIM). And also, the scaling and rotating factors of watermarks with multiple sizes are executed. The analysis of robustness quality is estimated by doing the subjective and objective quantitative analysis. Along with that, the existing techniques, total variation deviation (TVD) is discussed to consolidate the designed framework. The performance measures are explained as follows:

a *Normalised correlation*

NC is defined as the measure used for robustness of watermark images and the extracted watermark images. It is given as,

$$NC = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} W_{i,j} W_{i,j}^{*}}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} W_{i,j}^{2}}\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} W_{i,j}^{*2}}} \tag{10}$$

b *Peak to signal noise ratio*

PSNR depicts the analysis between the maximum power value of an image and the power of distorting noise. It portrays quality representation. It is given as,

$$PSNR(W, W) = 10\log\frac{W_{\max}^{2}}{MSE} \tag{11}$$

where

$$Mean\ square\ error\ or\ MSE = \frac{1}{M^2}\sum_{i=1}^{M}\sum_{j=1}^{M}\left(W_{i,j} - W_{i,j}^{2}\right) \tag{12}$$

$W_{\max}$ is the maximum value of a watermark image pixel.

c *Structural similarity index measure*

SSIM is the perceptual quality measurement that explores the pixel distortion during the watermarking extraction process. The predecessor and successor of the images are assessed. It is given as,

$$SSIM(W, W) = \mu_W \frac{\mu_{W^*+d_1}}{\mu_W^2 + \mu_{W^{*2}+d_1} \cdot \frac{\sigma_{ww^*+d_2}}{\sigma_w^2 + \sigma_{w^{*2}+d_2}}} \tag{13}$$

where

- $\mu_W \wedge \mu_{W^*}$ are the average of W and W^*
- $\sigma_w^2 \wedge \sigma_{w^{*2}}$ are the average of W and W^*
- σ_{ww^*} is the covariance of W and W^*
- d_1 and d_2 are the image analytics variables.

Figure 5 presents the details of considered input images. The cover image contains 512 ∗ 512 size and the watermark image contain 256 ∗ 256. These two images are fed into the preprocessing module that does the basic sampling techniques. The image is resized according to the mathematical operators. The pixel of an image is explored into greyscale conversion. In order to ensure the fine-grain image surface, the pixels of both images are preprocessed.

Figure 5 Cover image and the watermark image details

Figure 6 Applying DWT-HD-SVD technique

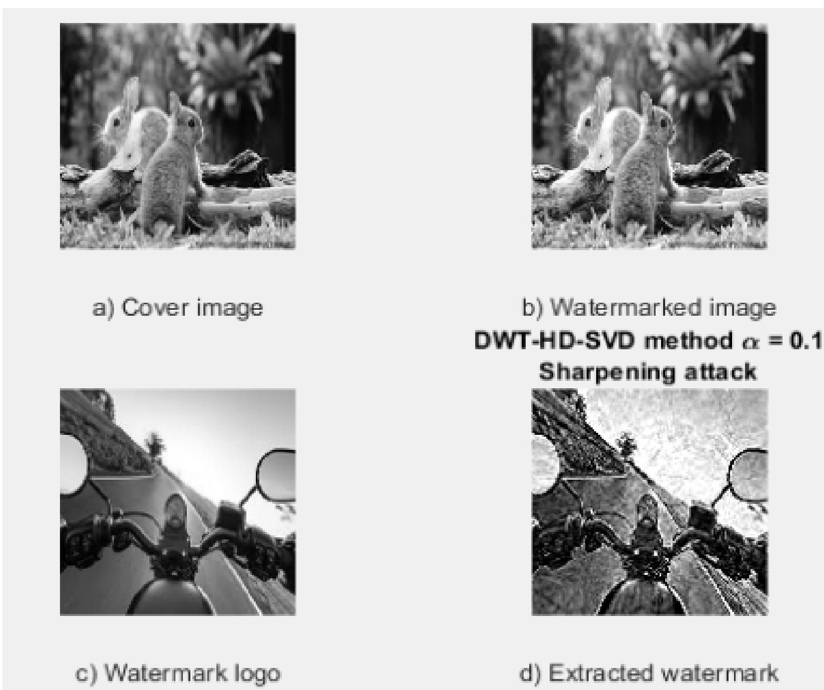


Figure 6 presents the image watermarking embedding process using DWT-HD-SVD technique. Generally, the source and the extracted watermark images are similar to the human visuals. Pertaining to this, the evaluation method is robust against these sharpening attacks, as $\alpha = 0.1$.

Figure 7 Analysis of DWT-HD-SVD under different scaling factors (see online version for colours)

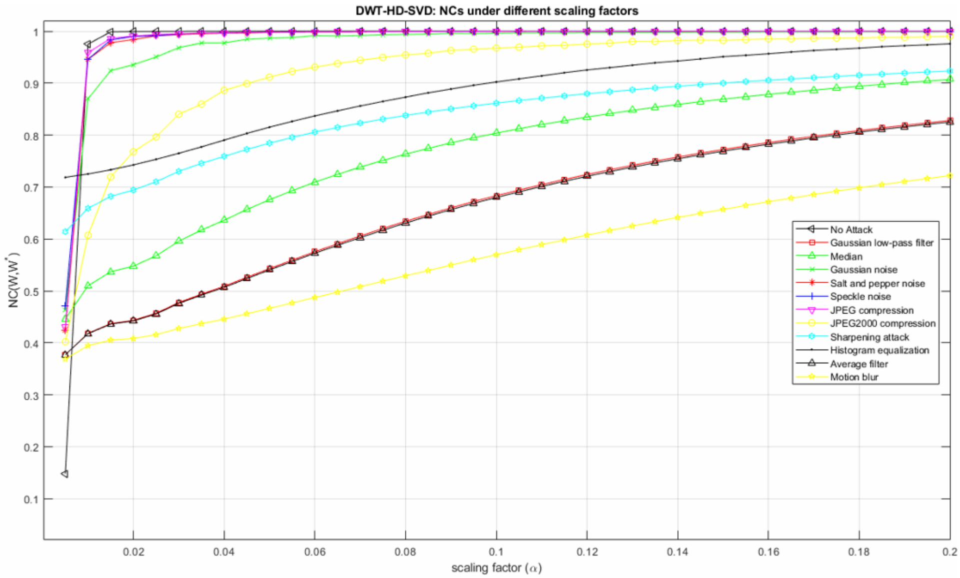


Figure 7 presents the DWT- HD-SVD analysis under different scaling and filtering attacks are observed. X-coordinates represents the scaling factor (α) and Y-coordinates represent the normalised coefficient. With the threshold of normalised coefficient, 0.5, the different attacks are experimented. The correlation value is less proving a robustness quality.

Figure 8 PSNR value analysis in DWT-HD-SVD (see online version for colours)

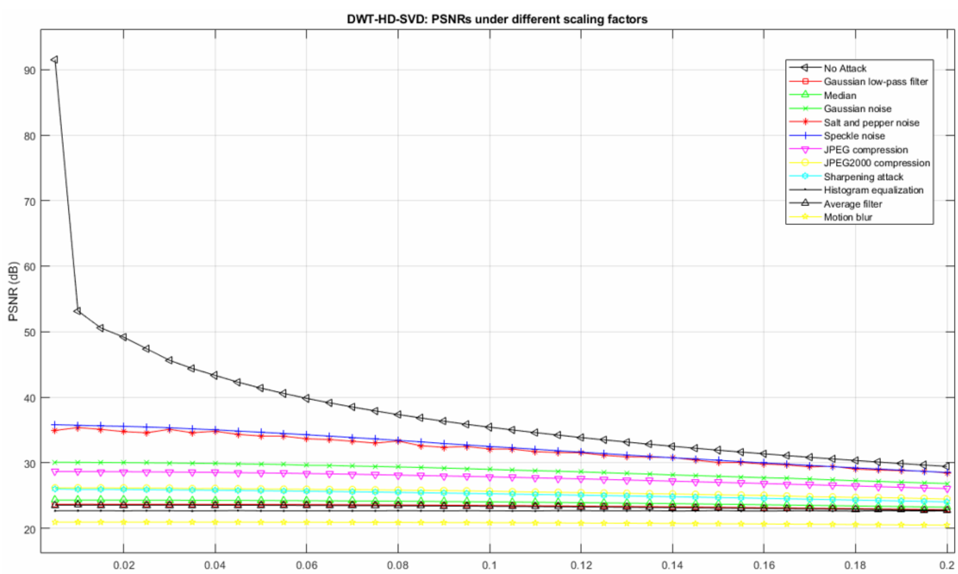


Figure 8 presents the PSNR analysis using the proposed techniques. X-coordinates represents the scaling factor (α) and Y-coordinates represent the PSNR. 35 dB PSNR value will make the watermark information to be invisible. Henceforth, the embodiments of watermark data range from 50.01 dB to 53.30 dB. It satisfies the conventional requirements of PSNR metric.

Figure 9 SSIM analysis in DWT-HD-SVD (see online version for colours)

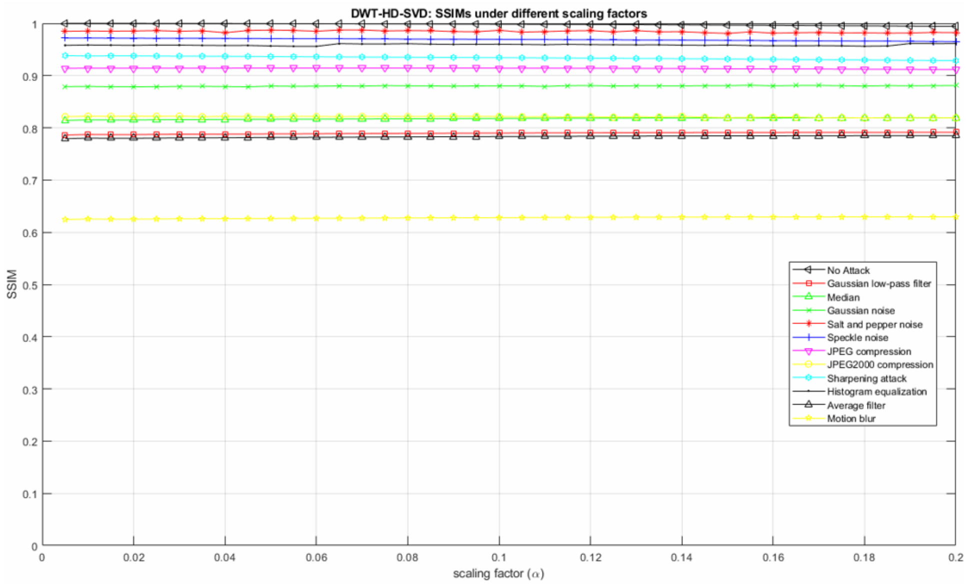


Figure 9 presents the SSIM analysis. The sequence length of the watermark is smaller in each block. The α value with the sequence length for each loop is analysed in an incremental process. The process is continued until the similarity threshold meets between the watermarked and the original blocks.

Table 1 PSNR and SSIM for watermark images with different sizes

Watermark image -size	*PSNR*	*SSIM*	*NC*
256 ∗ 256	36.4748	0.99861	0.99993
128 ∗ 128	42.3896	0.9995	0.99968
64 ∗ 64	48.423	0.99987	0.99929

Table 2 presents the PSNR and SSIM analysis of different attacks on three image sizes. The PSNR is for an embedding capacity on three image sizes. PSNR value is high, dictating a highly imperceptible and distortion in quality during the retrieval process is less. Moreover, the SSIM value is computed to be aware of the visual quality. It also proves that the visual quality is quite clear in the before and after embedding the watermarking process.

Table 2 PSNR and SSIM values for different attacks with different sizes

Types	*PSNR*			*SSIM*		
	256 ∗ 256	*128 ∗ 128*	*64 ∗ 64*	*256 ∗ 256*	*128 ∗ 128*	*64 ∗ 64*
No attack	48.423	42.3896	36.4748	0.9987	0.9995	0.99861
Gaussian low-pass filter	34.8203	34.391	32.9673	0.97277	0.97266	0.97318
Median filter	35.5203	34.9551	33.2458	0.97659	0.97627	0.97659
Gaussian noise	29.9929	29.8279	29.1801	0.76285	0.76347	0.76376
Salt and pepper noise	35.0296	33.9445	32.8662	0.9789	0.97633	0.97784
Speckle noise	36.1713	35.4075	33.364	0.94673	0.94591	0.94405
JPEG compression	37.8074	36.7936	34.2724	0.97522	0.97495	0.97437
JPEG 2000 compression	39.8393	38.2688	34.9814	0.98237	0.98211	0.98157
Sharpening attack	35.3852	34.6295	32.5768	0.98446	0.98389	0.98156
Histogram equalisation	19.2207	19.2014	19.2078	0.93074	0.93192	0.9329
Average filter	34.678	34.2609	32.8776	27.6998	0.97171	0.97226
Motion blur	0.97183	27.6331	27.3098	0.85758	0.85779	0.85834

Table 3 NC analysis from extracted watermark images for different image sizes

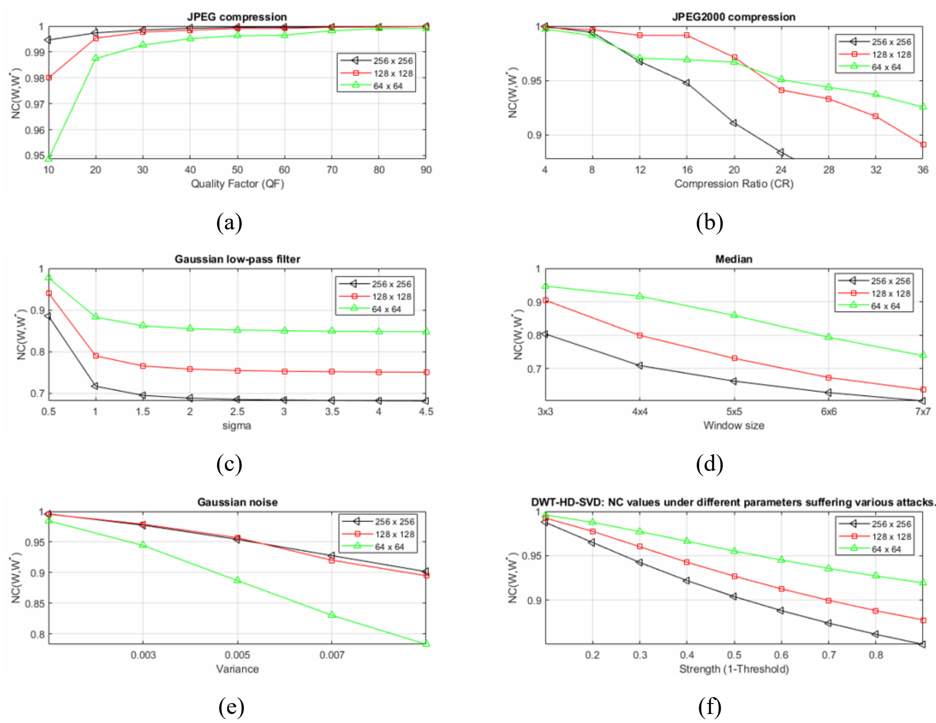
Types	*NCs*		
	256 ∗ 256	*128 ∗ 128*	*64 ∗ 64*
No attack	0.99929	0.99968	0.9993
Gaussian low-pass filter	0.90023	0.87123	0.88276
Median filter	0.97336	0.93464	0.93228
Gaussian noise	0.98755	0.99148	0.94807
Salt and pepper noise	0.9973	0.99827	0.98519
Speckle noise	0.99721	0.99844	0.98876
JPEG compression	0.99682	0.99883	0.99436
JPEG 2000 compression	0.99701	0.99778	0.99785
Sharpening attack	0.95857	0.94503	0.95021
Histogram equalisation	0.87238	0.88114	0.89775
Average filter	0.89843	0.86908	0.88091
Motion blur	0.73499	0.73692	0.78258

Table 3 presents the NC analysis of watermarked images for different image sizes. It helps to discover the correlation values of watermarked images at three different sizes. From the proposed embedding process, it is clear that the different regions of an image are watermarked. The depth analysis of embedded watermarks might increase with the decrease in watermark size. Since the watermarks are distributed over a large area of the host source. The analysis of NCs for different image sizes is studied. The host and watermark sources are embedded in equal sizes. At different levels of attacks, the NCs are investigated. It is quite inferred a highly robust performance towards different attacks at different image sizes given by the proposed technique. The table 4 presents the comparison between existing and proposed performance achievements in terms of PSNR and SNR.

Table 4 Performance of error measures

Metrics	*Error value*
Proposed_PSNR	31.3150
Proposed_SNR	24.8124
Existing_PSNR (Liu et al., 2019)	23.5464
Existing_SNR (Liu et al., 2019)	18.4196

Figure 10 Performance analysis graphs NC values under different parameters suffering various attacks. (a) JPEG compression, (b) JPEG2000 compression, (c) Gaussian low-pass filter, (d) median filter, (e) Gaussian noise, and (f) sharpening (see online version for colours)



5 Conclusions

This research study proposes a novel watermarking technique, DWT-HD-SVD-based D-CNN is proposed to perceive the subjective and objective quality of the watermarking process. Numerical simulation execution is done to analyse the proposed technique. The achieved results prove the watermarked images have yielded better PSNRs, and SSIMs. It has proved the better visual quality. The deployed watermarks on the host image are by various attacks. With the help of relatively high normalised coefficients (NCs) value, the relevant data is extracted from the watermarked images. Regardless of it, the watermarks with variant sizes can lower the robustness of the methods. Conventional methods are compared with the proposed technique. The robustness of extracting information from watermark images is mainly analysed in this study. It is observed from the results that the highest performance yielded by the proposed technique in terms of defending the attacks such as filter, noise, JPEG compression, JPEG2000 compression and sharpening attack.

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