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A robust digital watermarking technique based on feature and transform method

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This paper proposed a new robust digital watermarking technique with an aim of image protection. The proposed technique incorporates both the transform and feature methods. Initially, the Harris Laplacian detector extracts the features from the cover image that suites well for the watermarking. The extracted characteristic regions are grouped to form a primary feature set where the secret message is embedded to form a watermarked image. This image is tested by introducing six different predefined attacks, which checks the robustness of the extracted feature. Discrete cosine transform (DCT) transformation method extracts the secret message from the watermarked image. According to the results, the watermarked image is vulnerable to the undefined attack. To enhance the resistance against those attacks the primary feature set is extended by adding some auxiliary features. These features are extracted through Knapsack algorithm. The watermark is embedded into these auxiliary features where the secret message is not affected by any attacks. The experimental results show that the proposed watermark technique is efficient and also preserves the image quality.

Key words: Feature detector, Knapsack algorithm, watermark protection, attack resistant, digital watermarking.

INTRODUCTION

The growth of the Internet has paved a new way for preparation and delivery of data in the digital format. Web applications, digital libraries, real-time audio and video delivery are some of the applications of the Internet. A major problem faced by these applications is the copyright prevention. This has created the research interest towards the new copyright protection mechanism. Digital watermarking is one such technique that has attracted many research scholars. It is the process of embedding the secret data/information into a multimedia content. The embedded information can be later extracted or detected for prevention. Commercialization of watermarking becomes essential to address the problem that is created by the proliferation of digital information. In general, the digital watermarking can be classified into two groups namely fragile and robust.

Implementation of digital watermarking has the following issues (1) Capacity, (2) Robustness, (3) Transparency, and (4) security. As this paper aims for copyright protection, it uses the robust digital watermarking technique. Since robust based watermarking has an ability to recognize the embedded watermark even after various attacks. The effectiveness of the proposed watermark depends on the resistance against various attacks. The attacks are usually introduced to either invalidate or destroy the embedded watermark, which can be divided into two categories namely (1) geometric distortion, and (2) noise like signal processing. Attack of first type causes the detection of watermark in an image to fail by the watermark detector even when the watermark still in the image. There are various kinds of the mechanism to protect against the geometric distortion namely, feature-based scheme (Wei et al., 2005), pilot-based scheme (Manuel and Fernando, 2002), and transform-based scheme (Ante et al., 2011). The second type of attack consistently tries to remove the

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watermark from the cover image like de-noising, compression and low-pass filter.

Therefore, it becomes mandatory to resist against the attacks. In order to address this issue a new technique has been proposed in this paper, which incorporates both the feature and transform-based watermarking technique. The features that resist against different attacks can be determined through a good feature detector. Therefore, an excellent feature detector plays a key role in the feature-based watermarking techniques. Numerous number of feature detectors are available. From those detectors Harris Laplacian detector (Seo and Yoo, 2006) is used to obtain the feature points from the cover image. These features are referred as the primary features. The watermark is embedded into these features. To test the robustness, six different attacks have introduced and applied to the watermarked image. In order to find the resistance level, the watermark is extracted using discrete cosine transform (DCT) transform method and tested. The results show that watermark resists against pre-defined attacks whereas it has less robustness against the undefined attacks. Further the usual feature-based technique has the following two different issues:

(i) Repeated selection of characteristic region.
(ii) Complexity in determining smallest feature region.

To address the first issue, it is highly preferred to choose non-overlapping regions, which avoids the degradation quality of an image. The selected region normally has various degrees of resistance against different attack. Therefore, to overcome the second issue auxiliary feature selection is implemented using knapsack-algorithm.

RELATED WORKS

This part of the work deals with the recent research works that were carried out for the past seven years. The works discussed below focused on robust watermarking techniques based on feature and transform methods.

Singular value decomposition (SVD) based technique was proposed in (Chih-Chin, 2010), which explored the D and U components for watermark embedding. This technique preserves two properties namely non-symmetric and one-way. This work was followed by Lagzian et al. (2011) with the objective of providing imperceptibility and robustness requirements. The objective was achieved through a hybrid watermarking scheme that incorporated two models namely discrete wavelet transform (DWT) and SVD. The watermark was embedded to the elements of singular values of cover image's DWT sub-bands. Similarly, Li (2009) also used DWT and SVD technique for watermarking but the process of embedding the watermark differs. In addition, it used the Arnold transform to provide security to the watermark. The model proposed in (Chang et al., 2005) differs from the last two aforementioned techniques by using redundant discrete wavelet transform (RDWT) instead of DWT and SVD. Here, RDWT was applied to watermark and cover image, and SVD was applied to the LL sub-bands. Another technique was proposed in (Rastegar et al., 2011), which also used the SVD technique. This method has taken Finite Radon Transform (FRAT) along with SVD for watermarking.

Some techniques have used only the transform techniques for watermarking. A robust digital watermarking scheme was proposed based only on DWT (Chih-Chin et al., 2010; Ding et al., 2002). This method has two distinguished characteristics that were represented below. (1) This technique was adoptable to different gray images, and (2) It uses Arnold transform as in Ante et al. (2011) for resistance against the attacks. The method proposed by (Bors et al., 1996) uses the discrete cosine transform. Here two different constraints are considered. The first approach consists of embedding a linear constraint among selected DCT coefficients and the second one defines circular detection regions in the DCT domain. Is added in the paper and it is highlighted. The method proposed (Kasmani et al., 2008) has used Discrete Cosine Transform (DCT) along with DWT. Likewise Li (2009) has proposed a new robust watermarking algorithm based on DWT-DCT transform. Here, both the imperceptibility and robustness were achieved through embedding the PN-sequence of watermarked bits in the middle frequencies of DCT. In Lee et al. (2005) a region based digital watermarking technique was proposed based on DCT for copyright protection. The embedding of watermark into significant region was carried by Quantization Index Modulation (QIM). The significant regions were detected through quad tree. A high capacity reversible digital watermarking technique was proposed in Lu et al. (2006), which was based on integer-to-integer transform method. Here, the image was divided in non-overlapping regions and the watermark was embedded into coefficients of each specified regions, which has high frequency wavelet.

Similar to the transform model, there are few other works that focus mainly on the features of the image for watermarking. The importance of the feature-based watermarking was presented in Kasmani et al. (2008), which reviewed the feature extraction procedures namely Harris corner detector and the Mexican Hat wavelet scale interaction. A robust watermarking scheme was proposed in Lee et al. (2005) and has used watermark template match and feature point detection. Here, a scale interactive model was implemented to determine the features of the original image. Depending on that the watermark template was built and embossed into the local region of these points. A scale shape theory based watermarking technique was proposed (Lu et al., 2006; Seo and Yoo, 2006). A new watermarking technique which depends on the image's invariant region was proposed in Phadikar et al. (2011). This method used scale invariant technique to determine the region for embedding the watermark, which was robust against the attacks that were caused by geometric transformation. The technique proposed in Seo and Yoo, (2006) uses the Harris Laplace detector to find the feature points of the

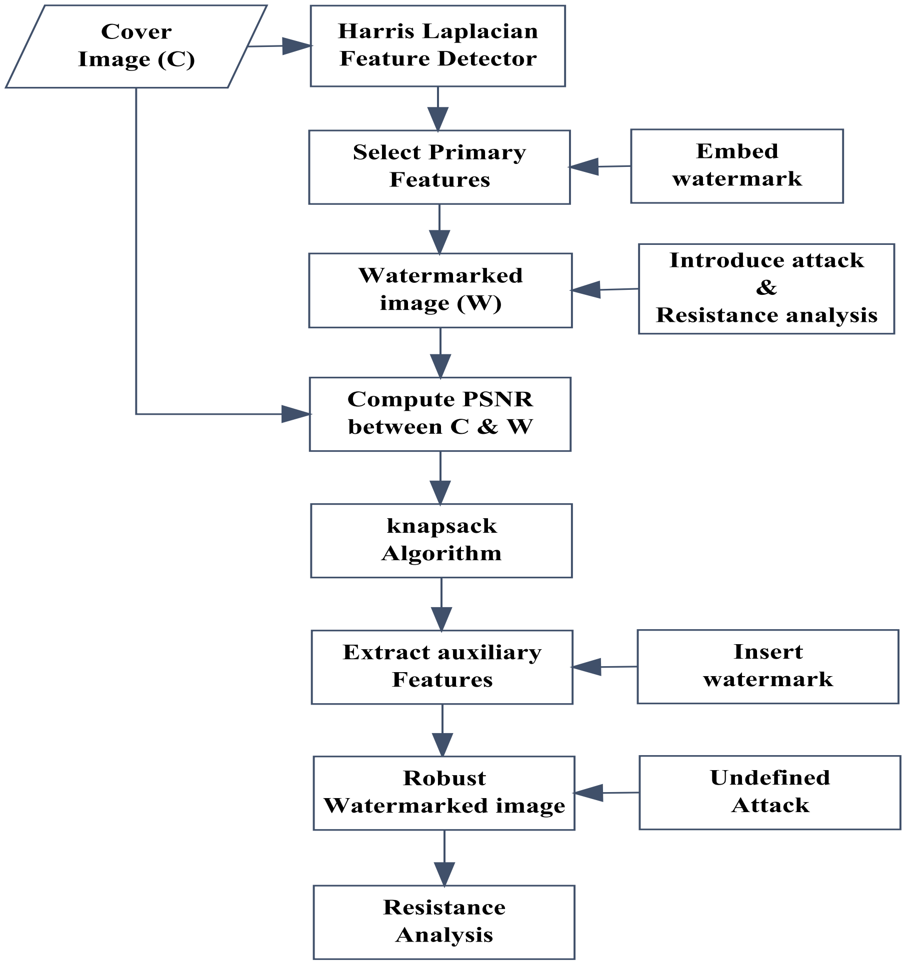


Figure 1. Overall flow of proposed watermarking technique.

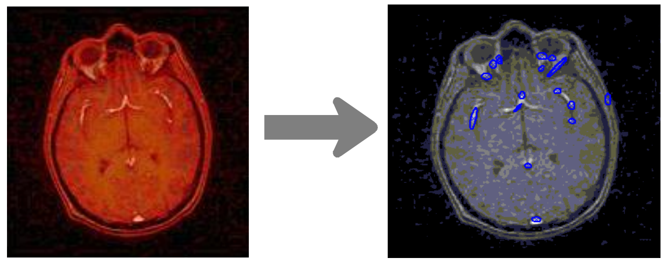
cover image. Several copies of watermark were embedded into the non-overlapping normalized LFR by comparing the DFT mid-frequency magnitude. This technique was robust as well as invisible against various attacks.

In Wang et al. (2008) and Jen-Sheng et al. (2007), Hessian-Affine and Hessian-corner detectors were used respectively for determining the feature points of the given input image. The main aim of Wang et al. (2008) was to provide the watermark authentication and protection. Through the detector, it detects the features of the cover image for embedding the watermark. Embedding process is carried using the orientation of each pixel. This technique was robust against geometric attacks. In Jen-Sheng et al. (2007) the watermark was embedded in the domain of Fourier frequency of the feature points that were generated from the Hessian-corner detector. This technique was robust against the local attacks that were common to the image processing. Other feature detectors namely SURF (Weinheimer et al., 2006), SIFT algorithm (Pan-Pan et al., 2012), and multi-resolution (Xiao-Chen and Chi-Man, 2012) were used for feature-based watermarking technique. Finally in Jen-Sheng et al. (2011), an algorithm was proposed to resist against the undefined attacks. It selects the primary features set using Harris Laplacian detector and refines the feature set by adding some auxiliary feature region using multidimensional knapsack algorithm.

The techniques that have been discussed so far have used any one of the following technique namely transform-based, SVD-based, feature-based methods; otherwise it was the combination of transform-based and SVD-based method or the combination of two different transform methods. But no work has combined the transform and feature-based method. In this paper, the proposed method combined the feature-based method and transform-based technique to improve the resistance against the attacks.

PROPOSED METHOD

Here the proposed process of watermarking is elaborated. The proposed technique extracts the primary features from the cover image using Harris Laplacian detector. To enhance the robustness of watermarking, knapsack algorithm is used to select the auxiliary features of the cover image. Figure 1 shows the overall flow of the



(a) Cover Image **(b) Feature detection**

Figure 2. Feature extraction from cover image.

proposed method. Analysis of the resistance shows the robustness of the watermarked image against predefined and undefined attacks. Following "primary feature detection" part of this work explains each process presented in the flow diagram in detail.

Primary feature detection

Harris Laplacian, a detector employed in this proposed watermarking technique to determine the feature points of the cover image. The detector has the following five steps to determine the feature points of the proposed technique.

(i) Initial points are selected along with the characteristic scale through the detector.
(ii) Use second moment matrix to determine the shape.
(iii) Normalize the region that are in ellipse to circular one.
(iv) Location and scale of the points are refined.
(v) If a new point is not isotropic then go to second step.

Initial points are determined using a matrix, M that is shown in the Equation (1).

$$M = (z, \delta_D) = \begin{vmatrix} D_{xx}(z,\delta_D) & D_{xy}(z,\delta_D) \\ D_{xy}(z,\delta_D) & D_{yy}(z,\delta_D) \end{vmatrix} \quad (1)$$

In Equation 2, the coordinate of the points (x, y) is represented as z, δ_D denotes the scale differentiation, and the D_{ij} expresses the second derivative of the point with respect to the variables i and j variables. A point is considered to be a primary feature only when the point is local minimum with respect to second derivative test. Laplacian of Gaussian (LoG), a scale selection function is employed to deal with the changes in the scale, which is represented in Equation (2).

$$|LoG(z, \delta_s)| = \left|\delta_s^2 \left(D_{xx}(z, \delta_s) + D_{yy}(z, \delta_s)\right)\right| \quad (2)$$

The Gaussian scale factor at the scale s is denoted as δ_s in Equation (2). The operator responses for a set of scales δ_s are manipulated. Maximum response is obtained only when the size of the bob-like structure matches with the LoG kernel. Following this, elliptical region of the feature point is determined using the second order matrix, σ, of a point as given in Equation 3.

$$\sigma(z, \delta_I, \delta_D) = \delta_D^2 S(z, \delta_I) * \begin{bmatrix} D_x^2(z, \delta_D) & D_x D_y(z, \delta_D) \\ D_x D_y(z, \delta_D) & D_y^2(z, \delta_D) \end{bmatrix} \quad (3)$$

In Equation 3, δ_I expresses the integration scale. These elliptical points are converted into circular points using square root of the second moment matrix of the point. The circular regions are given as input to the detector to find the new feature point having new differential scale. Finally, the original image is compared with the new feature point's Eigen values of second moment matrix. If they are not equal then the process is repeated still both values become equal. Figure 2 represents the extracted feature of a cover image.

Watermark insertion into the primary feature

The main objective of the proposed watermarking technique is to embed the watermark into the cover image without the loss of perceptual quality of the image. To achieve this objective, this paper has used Noise Visible Function (NVF) for a pixel, z, in an image can be determined through the Equation (4).

$$NVF(z) = \frac{1}{1+\theta \cdot l(z)}, \theta = \frac{E}{l_{maximum}} \quad (4)$$

In Equation (4), $l_{maximum}$ and $l(z)$ denote the maximum local variance of the image and the local variance of the pixel respectively. The E is an experimentally determined constant. The embedding function in (5) is used to embed the watermark into the selected circular points.

$$P_w(z) = P(z) + \left(1 - NVF(z)\right) \cdot S_w(j) \cdot w_1 + NVF(z) \\ S_w(j) \cdot w_2 \quad (5)$$

Here, $P(z)$ gives the pixel z's original value where as $P_w(z)$ denotes the value of pixel when embedded with the sequence of watermark, $S_w(j)$. w_1 and w_2 are the experimentally determined values. Figure 3 shows the picture of watermarked image.

Types of attacks

Compression attack

JPEG compression is used in number of file formats. The images may be better saved in a lossless graphics format such as TIFF, GIF, PNG or a raw image format. Practically all images currently being distributed via Internet have been compressed. If the watermark is required to resist different levels of compression, it is usually advisable to perform the watermark embedding in the same

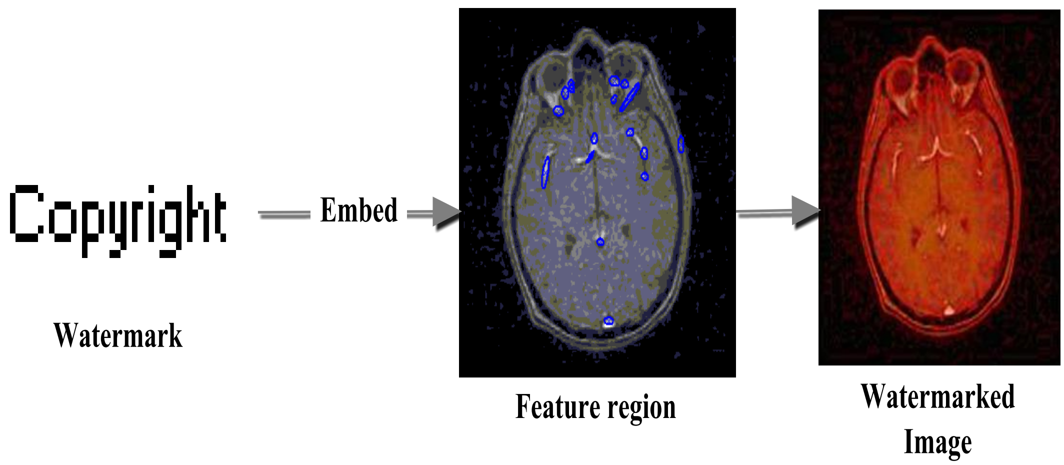


Figure 3. Watermarked brain Image.

domain where the compression takes place. For instance, the Discrete Cosine Transform (DCT) domain image watermarking is more robust to Joint Photograph Expert Group (JPEG) compression than the spatial-domain watermarking. Also, the Discrete Wavelet Domain (DWT) domain watermarking is robust to JPEG 2000 compression (Andreja and Jan, 2008).

Noise attack

A random signal with a Gaussian, uniform distribution is added to the image unintentionally. In certain applications the additive noise may originate from Digital-to-Analog (D/A) and A/D converters or as a consequence of transmission errors. But, an attacker may introduce perceptually shaped noise with the maximum unnoticeable power. This will naturally force to increase the threshold at which the correlation detector operates.

Filtering attack

Filtering attacks are high-pass, low-pass, Gaussian and sharpening filtering, etc. Low-pass filtering, for instance doesn't introduce considerable degradation in watermarked images, but can severely affect the performance since spread-spectrum-like watermarks have non negligible high-frequency spectral contents. To design a watermark robust to a known group of filters that might be applied to the watermarked image, the watermark message should be designed in such a way to have most of its energy in the frequencies which filters change the least.

Geometrical attacks

These attacks are not aimed at removing the watermark, but try to either destroy it or disable its detection. They attempt to break the correlation detection between the extracted and the original watermark sequence, where the image is subjected to translation, rotation, scaling and/or cropping. This can be accomplished by "shuffing" the pixels. The values of corresponding pixels in the attacked and the original image are the same. However, their location has changed. These attacks can be subdivided into attacks applying general affine transformations and attacks based on projective transformation. Cropping is a very common attack since in many cases the attacker is interested in a small portion of the watermarked object, such as parts of a certain picture or frames of video sequence. With this in mind, in order to survive, the watermark needs to be spread over the dimensions where this attack takes place.

Resistance analysis against the various attacks

To analyze the resistance against the various attacks this paper has introduced six different pre-defined attacks namely, (1) JPEG compression, (2) Noise, (3) Wiener Filter, (4) Sharpening the image, (5) Median filter, and (6) Scaling. The robustness is computed by comparing the extracted watermark with the original image. The watermark is extracted after the images to which the attack has been introduced. Here, the watermark is extracted using DCT transform model. The extraction process is carried out using the following steps.

1. The watermarked image is transferred into frequency domain through DCT approach
2. The feature points used for embedding is also used for extraction process
3. The accurate location of the DCT block in the watermark image is determined through the applying the feature points
4. Extract the watermarked data from the DCT block

For comparison, bit-error difference is computed. A predefined threshold TH is introduced, to determine the existence of the attack in the image. Equation (6) represents the determination of existences of attack in the watermark image.

$$I_{E,a} = \begin{cases} 1, & BER(W, W_E) \leq TH \\ 0, & Otherwise \end{cases} \quad (6)$$

From the Equation (6) it is evident that if the bit-error rate is lower than the TH then the attack does not exist. W and W_E denotes the original and the embedded watermark. Figure 4 portrays an example attacked images and the extracted watermark from the corresponding attacked image.

The experiment is conducted for total 150 images. Under each category 50 images are taken. Here Computer Tomography, Magnetic Resonance Imaging and X-ray images are considered and the results for randomly chosen five images are shown in the Table 1. The resultant values show the bit-error rate difference. The experiment is computed by setting the threshold value as 10. The results show that the watermark is highly affected by the noise

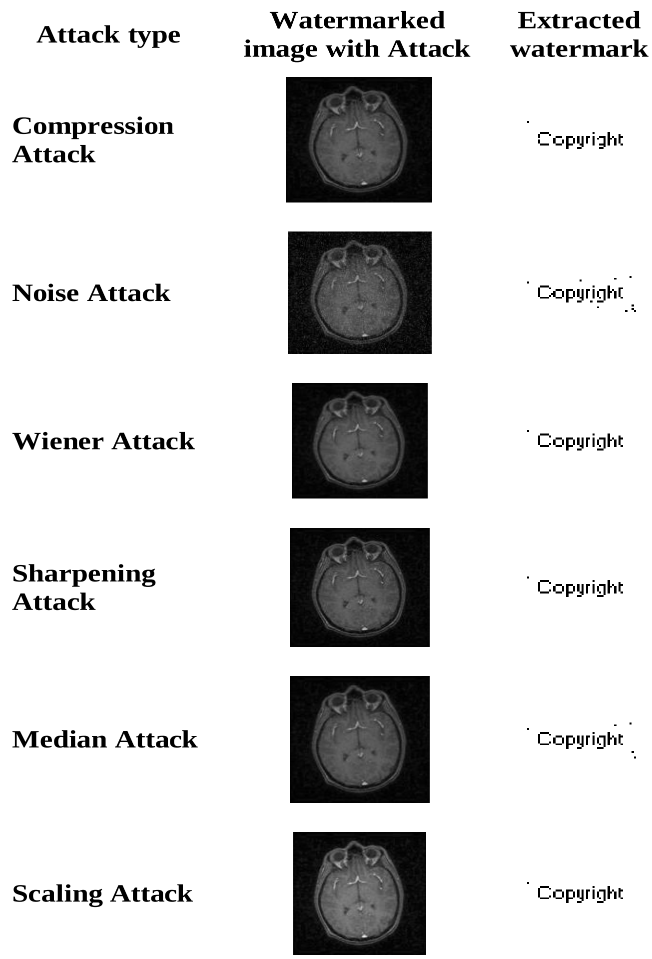


Figure 4. Example of attack introduced image and the extracted watermark.

Table 1. BER evaluation results for Primary Feature set watermark embedding.

Attacks/Images	CT-1	CT-2	MRI-1	MRI-2	X-ray-1	X-ray-2
JPEG	7.3950	0	0.7650	1.7850	4.0800	6.1200
Noise	15.8100	14.7900	3.8250	3.0600	6.8850	8.6700
Wiener Filter	9.4350	5.8650	0.7650	1.7850	5.3550	10.965
Sharpen	5.3550	0	0.7650	1.7850	4.0800	4.3350
Median Filter	9.6900	9.6900	1.7850	2.0400	5.6100	7.3950
Scaling	6.1200	0	0.7650	1.7850	4.0800	4.8450

attack.

Auxiliary feature detection

The resistance analysis part of this paper shows that embedding watermark in the primary feature has less resistance to the noise attack. Further, they are not robust against the undefined attack. Therefore, in order to deal with these drawbacks, auxiliary features are selected to enhance the resistance capacity of the watermarked image without affecting the quality of the image. Dealing with undefined attack is difficult to model as well as they are of wide variety. So, the auxiliary feature selection strategy proposed in this paper has an assumption that the feature points, which resist against various types of predefined attacks are most likely to be more robust against undefined attacks.

The optimization problem during auxiliary feature selection is addressed through the multi-criteria strategy. While choosing these auxiliary features, a problem named knapsack problem arises. This problem is addressed through a heuristic search procedure named knapsack algorithm. The knapsack problem can be defined using a collection of different constraints through the equation (7) and (8).

Maximize $\sum_{z=1}^{x} R_{r_z} P_{r_z}$ (7)

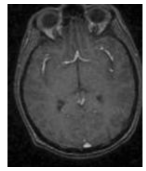
Undefined Attack	Watermarked image with Attack	Extracted watermark
Cropping		

Figure 5. Example of an undefined attack.

Table 2. BER evaluation results for Auxiliary Feature set watermark embedding.

Attacks/Images	CT-1	CT-2	MRI-1	MRI-2	X-ray-1	X-ray-2
JPEG	7.3250	0	0.7550	1.6850	4.0512	6
Noise	15.7100	14.761	3.790	3.0	6.6850	8.3700
Wiener Filter	9.2000	5.8650	0.7650	1.7850	5.3550	10.2000
Sharpen	5.3550	0	0.7650	1.7850	4.0800	4.3350
Median Filter	9.6900	9.6900	1.7850	2.0400	5.6100	7.3950
Scaling	6.1200	0	0.7650	1.7850	4.0800	4.8450
Cropping	6.1200	0	0.7650	1.7850	4.0800	5.1000

Subject to $\sum_{z=1}^{x} cw_{k,r_z} P_{r_z} \leq y_k, \quad k = 1,2, \ldots\ldots, m$ (8)

Where P_{r_z} can be obtained through the Equation (9).

$$P_{r_z} = \begin{cases} 1, & \text{if the region } r_z \text{ is selected} \\ 0, & \text{Otherwise} \end{cases} \quad (9)$$

In Equation (7), symbol x represents the total number of non-overlapping regions, R_{r_z} denotes the overall resistance degree of the region r, which is determined using the Equation (8).

$$R_{r_z} = \sum_{i=1}^{T_{pa}} S_{r,pa_i} \quad (10)$$

Here, T_{pa} is the total number of predefined attacks and $S_{r,pa_i} \in \{0,1\}$ that express weather the region r can resist the predefined attack i. In Equation (8), cw_{k,r_z} and y_k represent the composite weight and constraints of quality degradation and the capacity parameter of knapsack problem. The capacity parameter of an image is computed by considering the peak signal-to-noise ratio (PSNR).

Peak Signal to Noise Ratio: The maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Reasonably, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the modified pixels in watermarked image. So, if a data embedding scheme having a lower MSE (and a high PSNR), it is recognized as a better one.

$$\text{PSNR} = 10\log\left(\frac{255^2}{\text{MSE}}\right) \quad (12)$$

Structural Similarity Index Measure: The structural similarity (SSIM) index is a method for measuring the similarity between two images.

$$\text{SSIM}(X,Y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x{}^2 + \mu_y{}^2 + c_1)(\sigma_x{}^2 + \sigma_y{}^2 + c_2)} \quad (13)$$

Resistance analysis against the undefined

Resistance against the undefined is estimated and an example of the attacked watermarked image and the extracted watermark is given in the Figure 5.

The images used for resistance analysis are used for measuring the robustness against the undefined attack. Equation (6) is used to determine the bit-error rate and the results are depicted in the Table 2. The experiment is computed by setting the threshold value as 10.

The results presented in the Table 2, denotes that the auxiliary features defeat against the attacks effectively than the primary features.

RESULTS AND DISCUSSION

In this experiment, six different images of brain are used, which are generated from CT, MRI, and X-ray scans. The primary features of these images are retrieved using the Harris-Laplacian detector and to enhance the robustness against the attack, auxiliary features are selected and watermark is inserted into it. Here, the robustness against the predefined attack and the undefined attack are tested based on the bit-error rate (BER) and the Structural Similarity (SSIM). This experiment has set 10 as threshold value for BER rate. Figures 6 and 7 show the

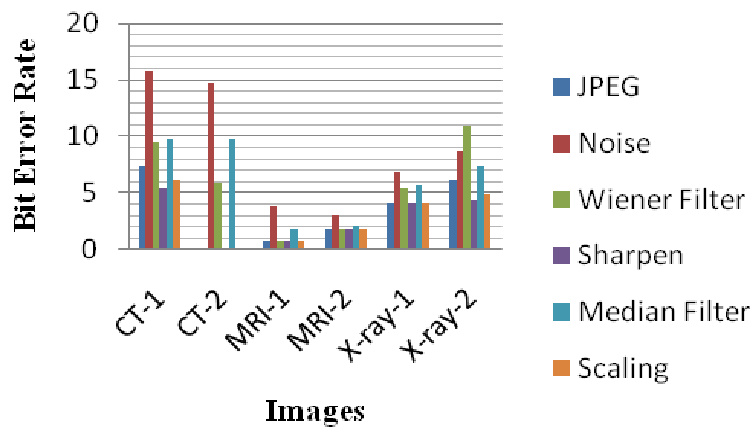


Figure 6. BER evaluation for dataset images using primary features.

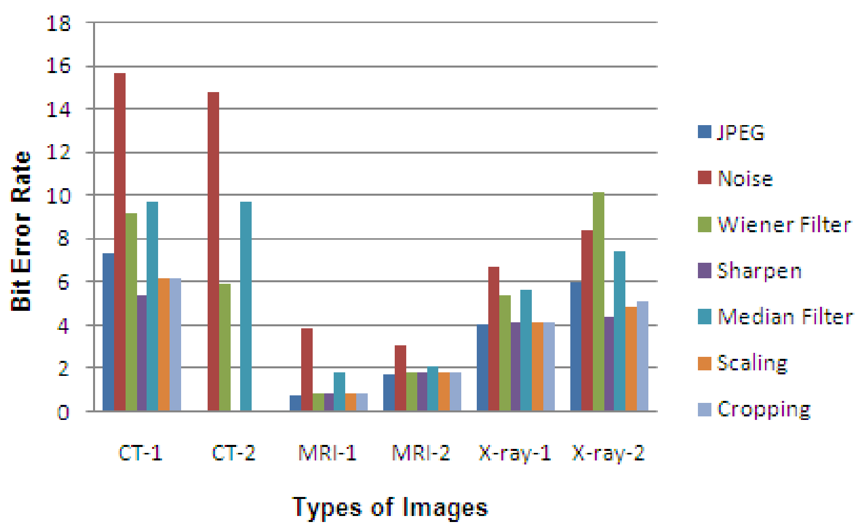


Figure 7. BER evaluation for dataset images using auxiliary features.

BER rate for watermarked image when the watermark is embedded in the primary and the auxiliary features.

From the Figures 6 and 7 it is evident that the auxiliary feature based watermarking has higher resistance against the attacks than the primary features. Therefore, the proposed system has higher resistance against various attacks. Similarly, the proposed technique is compared with the existing technique in terms of SSIM. Figures 8 and 9 show the SSIM values while using the primary and auxiliary features for embedding the watermark in the image. These graphs also portrays that the proposed system functions more perfectly than the existing technique (Table 3).

Conclusion

In this paper, a new robust watermarking technique has been proposed with an objective of providing protection to the image. Here, Harris-Laplacian feature detector is used to select the primary features from the cover image. The watermark is embedded into the extracted primary features, and its robustness against six different predefined attacks is evaluated using BER and SSIM. For the experimental purpose, the threshold value for BER is set as 10. The result analysis shows that the watermarked image is not robust against the noise attack. In order to enhance the resistance capacity, the watermarking process is improved by embedding the watermark into the auxiliary features of the cover image. The auxiliary features are determined using a knapsack problem. The watermarked image generated through embedding the watermark into the auxiliary features is tested against the predefined attacks along with an undefined attack. This work can be further improved by providing authentication using watermarking technique, which will be carried as future work.

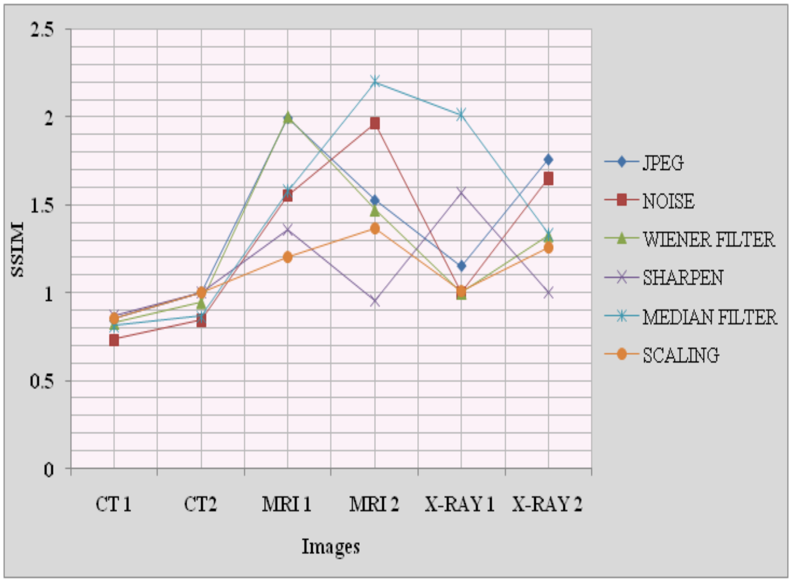


Figure 8. SSIM evaluation for dataset images using primary features.

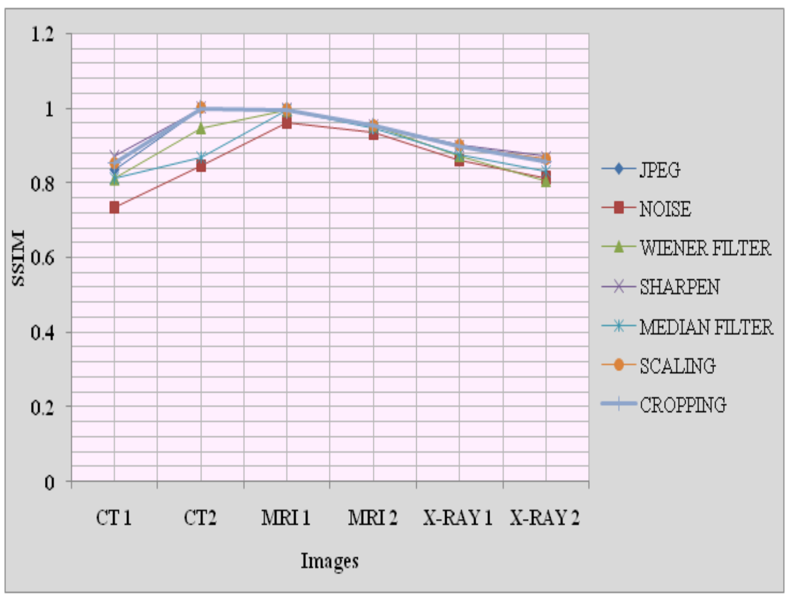


Figure 9. SSIM evaluation for dataset images using auxiliary features.

Table 3. Comparison with the existing method.

Title and author	Method	PSNR	SSIM
A benchmark for medical image watermaking (Navas et al., 2007)	EPR (electronic patient record) hiding using LSB technique	44	0.75
Feature based blind approach for robust watermaking (Sujatha et al., 2010)	DWT based blind image watermaking scheme	59.1168	0.8496
Proposed method	Auxiliary feature based watermaking and extraction using DCT	49.1447	0.9937

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