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SVD based digital image watermarking using Linear and Cosine interpolation method

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Abstract— Watermarking schemes allow a cover image to be embedded with a watermark image, for diverse applications including proof of ownership or for image hiding. In this study, a Singular Value Decomposition (SVD) based watermarking scheme using interpolation method is proposed where the watermark is added in the singular values of a digital image using interpolation method. The resultant watermarked image is treated with different distortion operation. Finally, the watermark is extracted for each method and each recovered wa-termark is compared with the original watermark using normalized correlation, Peak Signal to noise ratio and accuracy rate. A better method is prescribed based on comparison results. The selected method is implemented in real world application for the purpose of copyright protection, authentication, integrity etc.

Index Terms— Digital Watermarking, Copyright protection, Singular value decomposition, Linear and Cosine Interpolation, Authentication, Integrity.

1 INTRODUCTION

Digital watermarking is a technique of embedding some information (i.e. hidden copyright data) into an image. Number of applications has been found in various fields like copyright protection, content authentication, document annotation, medical imaging etc.

The rapid development of digital technologies has provided various ways to access information. These new technologies enable us to process digital con-tent with less time, lower complexities and better efficiency. However, digitization also brings disad-vantages like illegal reproduction and distribu-tion of digital content [1] .The spreading of digital mul-timedia nowadays has made copyright protection a necessity. Authentication and information hiding have also become im-portant issues.

2 LITERATURE REVIEW

The state-of-art in the literature will be reviewed to provide a foundation for the evaluation of the pro-posed approaches. Image watermarking is a well-known technique for copyright protection.

2.1 Digital image watermarking

"Watermarking" is the process of hiding digital in Formation in a carrier signal [1], [2]. Digital image watermarking implies adding some information in the cover image before it is posted globally.

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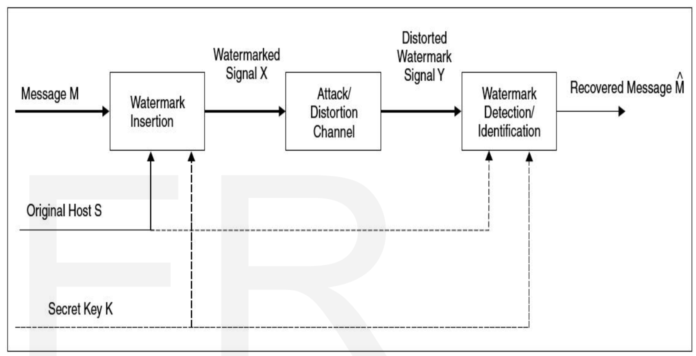

Figure 1: Block diagram of watermarking process

The information to be embedded is called a digital watermark. The signal where the watermark is to be embedded is called the host signal. A watermarking system is usually divided into three distinct steps

i. Embedding
ii. Attack
iii. Detection / Extraction

i. Embedding

An algorithm accepts the host and the data to be em-bedded, and produces a watermarked signal. Inputs to the scheme are the watermark, the cover data and an optional public or secret key. The outputs are wa-termarked data. The key is used to enforce security.

(1)

ii. Attacks

The watermarked digital signal is transmitted or stored. If any person makes a modification, this is called an attack. There are many possible modifica-tions, for example, lousy compression of the data (in which resolution is diminished), cropping an image or video or intentionally adding noise.

iii. Extraction

Extraction is an algorithm which is applied to the attacked signal to attempt to extract the watermark from it. If the signal was unmodified during trans-mission, then the watermark still is present and it may be extracted. Inputs to the scheme are the wa-termarked data, the secret or public key and, de-pending on the method, the original data and/or the original watermark. The output is the recovered watermarked W or some kind of confidence measure indicating how likely it is for the given watermark at the input to be present in the data under inspection.

Digital image watermarking should possess follow-ing charac-teristics:

i. Imperceptibility: The watermark should not affect the quali-ty of the original signal, thus it should be invisible/ inaudible to human eyes/ ears.

ii.Robustness: The watermarked data should not be removed or eliminated by unauthor-ized distributors, thus it should be robust to resist common signal processing manipula-tions such as filtering, compression, filtering with compression.

iii.Security: The watermark should only be de-tected by au-thorized person.

2.2 Singular Value Decomposition (SVD)

SVD is a linear algebra scheme developed for a vari-ety of ap-plications, particularly in least-squares problems. It also has been used in image processing applications that include image compression, image hiding and image watermarking because the singular values of an image do not change greatly when a small interference is added to an image[5],[1] .

Let I be an image matrix of size N x N. It can be rep-resented using singular value decomposition as:

$$I = U \cdot S \cdot V^T = \sum_{k=1}^{N} u_k \cdot s_k \cdot v_k^T$$

……eq^n (2.1)

with U=[u_1, u_2, ..., u_N], V=[v_1, v_2, ..., v_N], and

$$S = \begin{bmatrix} s_1 & 0 & \cdots & 0 \\ 0 & s_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & s_N \end{bmatrix}$$

……eq^n (2.2)

Here U and V are orthogonal matrices of size N x N whose col-umn vectors are the left-singular and the right-singular vectors, respectively. S is an N x N di-agonal matrix containing non-negative terms. The diagonal elements s1, s2, ..., sN of matrix are the sin-gular values of matrix I, satisfying the ordering: s1 s2... sN

It is important to note that:

• Singular values correspond to the luminance of the image (i.e., image brightness) and the corre-sponding singular vectors specify the intrinsic geometry properties of the image.

• Many singular values have small values compared to the first singular value s1. If these small singular values are ignored in the reconstruction of the image, the quality of the reconstructed im-age will degrade only slightly

• Slight variation of the singular values does not affect the visu-al perception of the image, i.e., singular values do have good stability.

2.3 Interpolation methods

Interpolation is a method of constructing new data points with-in the range of a discrete set of known data points. When we have a number of data points, obtained by sampling or experi-mentation, which rep-resent the values of a function for a lim-ited number of values of the independent variable, we need to interpolate (i.e. estimate) the value of that function for an inter-mediate value of the independent varia-ble. Research proved the interpolation method can be used to estimate the water-marked image.

2.3.1 Linear Interpolation

Linear interpolation is the simplest method of getting values at positions in between the data points. The points are simply joined by straight line segments. Each segment (bounded by two data points) can be interpolated independently. The parameter mu defines where to estimate the value on the inter-polated line, it is 0 at the first point and one and the sec-ond point. For interpolated values between the two points mu ranges between 0 and 1. Values of mu outside this range result in extrapolation [6].

```
double LinearInterpolate( double y1,double y2, dou-ble mu)
    {
    return(y1*(1-mu)+ y2*mu);
    }
```

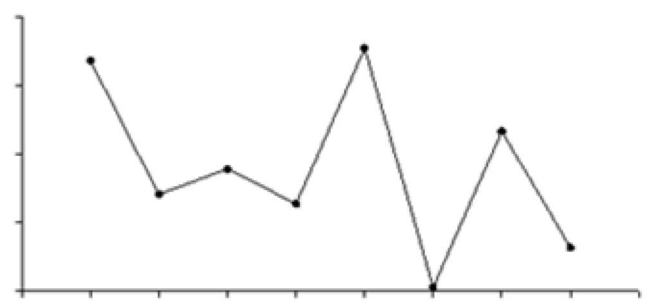

Figure 2: Linear Interpolation

2.3.2 Cosine Interpolation

Linear interpolation results in discontinuities at each point. For smoother interpolating function, the sim-plest is cosine interpolation. A suitable orientated piece of a cosine function

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serves to provide a smooth transition between adjacent segments.

```
double CosineInterpolate (double y1, double y2, double mu)
        { double mu1;
          mu1 = (1-cos(mu*PI)) / 2;
        }
```

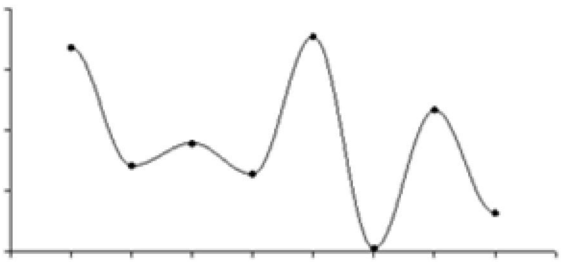


Figure 3: Cosine Interpolation

2.4 Previous Work

Most of the work done previously combines SVDs of cover image and watermark image using linear interpolation [7]. Some works done are based on im-plementing watermark by breaking the cover image into block and adding watermark in each block [4]. Some work replaces the singular value of cover im-age with that of watermark image [1]. Some directly adds the singular values of cover image into water-mark image [3], [4].

In this paper, it is proposed that instead of adding SVDs of cover image and watermark image using linear interpolation, we can use cosine interpolation to yield the better result. Hence this paper will be the extension of previous work by adding extra step of cosine Interpolation over linear interpolation

3 Research Methodology

Digital watermarking algorithm was based on two mathematical techniques: Singular value decomposi-tion (SVD) and Interpolation method viz. Linear and Cosine interpolation method.

A cover image and watermark image were decom-posed into respective SVDs. Then the singular value of watermarked image was found by using interpolation method. Then inverse SVD was performed. Then various attacks were applied on watermarked cover image. Then the watermark image was ex-tracted from the distorted image and was compared with original one.

3.1 Algorithms:

3.1.1 Watermark embedding algorithm

i. The SVD was performed on the cover image ‘Ic’ and watermark image ‘Iw’ as:

Ic=Uc Sc VcT ……eqn .(3.1)

Iw=Uw Sw VwT ……eqn (3.2)

ii. Now Sw of Watermark image Iw was added to Sc of cover image Ic. as:

Method-1	Method-2
• $U_{wi}=U_c$ • $S_{wi}=(1-t)S_w+tS_c$ • $V_{wi}=V_c$	• $U_{wi}=U_c$ • $t_1=(1-\cos(t*PI))/2$ $S_{wi}=(1-t_1)S_w+t_1S_c$ • $V_{wi}=V_c$

iii. Now the watermarked image Iwi was ob-tained by using U_{wi}, S_{wi} and V_{wi} as:

$I_{wi}=U_{wi}\,S_{wi}\,V_{wi}^T$ ……eqn (3.3)

The watermarked image Iwi was also attacked by dif-ferent operations like blurring, filtering, compression, noise addition etc.

3.1.2 Watermark extraction algorithm

Given I_{wi}, I_w, t & I_c, embedded watermark was extracted as:

i. The SVD was performed on watermarked image I_{wi} and watermark image I_w:

$I_{wi}=U_{wi}\,S_{wi}\,V_{wi}^T$ …eq^n (3.4)

$I_w=U_w\,S_w\,V_w^T$ …eq^n (3.5)

$I_c=U_c\,S_c\,V_c^T$ …eq^n (3.6)

ii. Now singular values of extracted watermark image I_{ew} was calculated as:

Method-1	Method-2
• $U_{ew}=U_w$ • $S_{ew}=(S_{wi}-t*S_c)/(1-t)$ • $V_{ew}=V_w$	• $U_{ew}=U_w$ • $t_1=(1-\cos(t*PI))/2$ $S_{ew}=(S_{wi}-t_1*S_c)/(1-t_1)$ • $V_{ew}=V_w$

iii. Now the watermarked image Iew was ob-tained by using Uew, Sew and Vew as:

$I_{ew}=U_{ew}\,S_{ew}\,V_{ew}^T$ ……eq^n (3.7)

iv. Then the comparison of original watermark image Iw with obtained watermark image Iew was performed using different parameters.

v. Now, the comparison parameters Normalized Correlation (NC), Accurate Rate (AR) and PSNR were calculated.

vi. Finally, based on these two metrics the better algorithm was justified.

These whole operations are performed for different values of ‘t’.

3.2 Research Model

Proposed methodology is best shown in figure 4. Cover image and watermark images are decomposed into corresponding singular values. Then interpola-tion method is used to watermark the cover image. Then the reverse SVD process is applied to generate the watermarked process. Different attacks are done over the watermarked image. Then we extract the watermark from the attacked watermarked image using the same SVD and reverse interpolation meth-od, as depicted by the following flowchart.

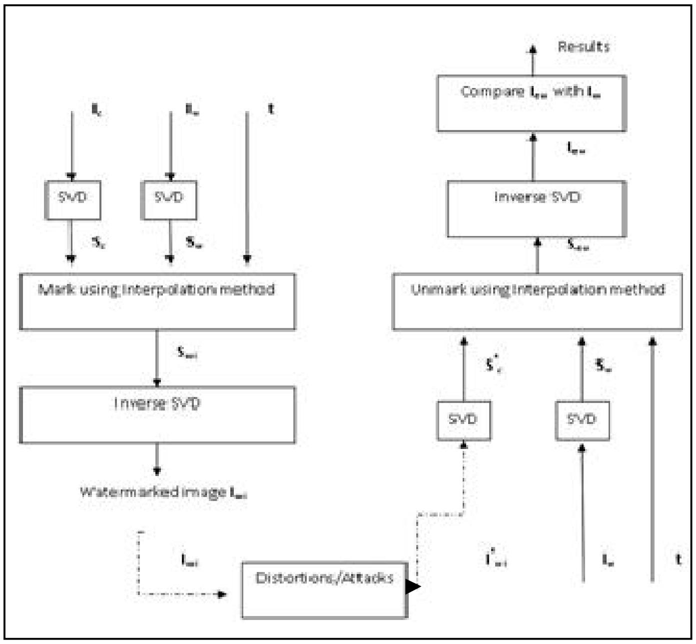


Figure 4: proposed watermarking scheme

4 Performance Measures

Performance measurement is the process of collect-ing, analyzing and/or reporting information regarding the performance parameters of an individual, group, system or component.

The following comparison metrics are used:

- Normalized Correlation (NC)
- Accuracy Rate (AR)
- Peak Signal-to-Noise Ratio (PSNR)
- Execution time

5 System Validation Schemes

The system validation scheme is mechanisms which are validate the system for checking Imperceptibility and Robustness.

Two types of validation were done.

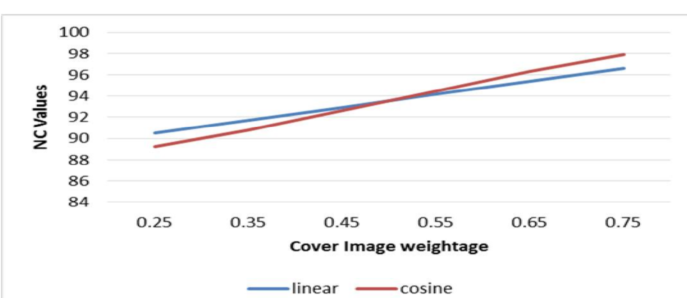
- Imperceptibility validation
- Robustness validation

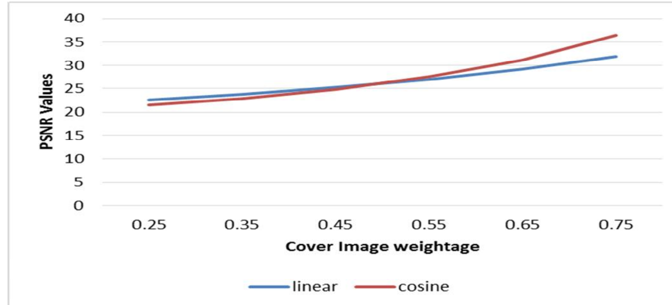
6. Observation and Discussion

Analysis was done on the basis of following major factors

6.1 On the basis of imperceptibility

During watermark addition, the imperceptibility fac-tor is important. This was measured by following:





6.1.2 Analysis

Studying the above graphs, we found that cosine method yielded better NC and PSNR values as com-pared to linear interpolation. Cosine interpolation method provided better values than linear. It is true even for the lower weight of cover image. Looking at the values of NC and PSNR and result of water-marked image, we can say this method provides good imperceptibility to the cover image.

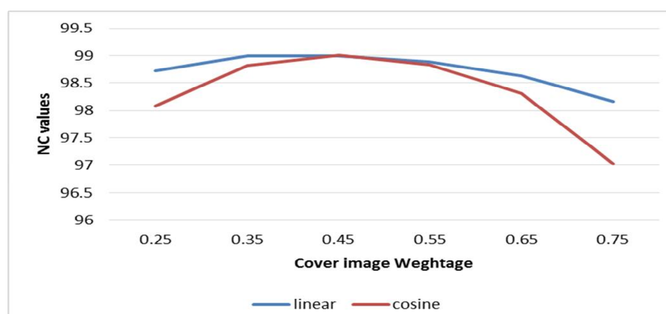
The reason behind this is that the SVD technique provides good stability to the system under decom-position. It resists the changes made to its singular values; as a result the overall system looks same and stable. Also cosine method provides good approxi-mation of the intermediate values. As a result the required imperceptibility is achieved.

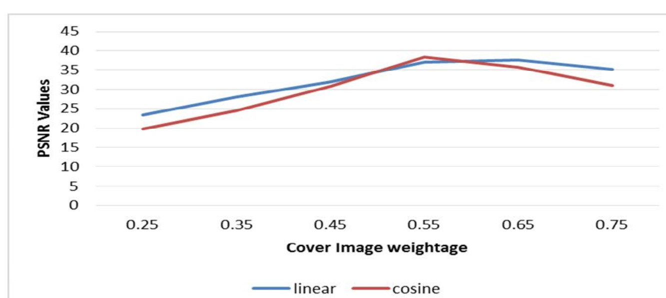
6.2 On the basis of robustness

During watermark extraction, the robustness factor is important. Here the NC and PSNR values were cal-culated for different attacks. This was measured by following:

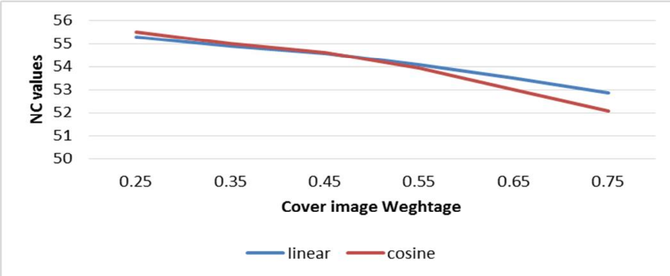
6.2.1 Obtained data

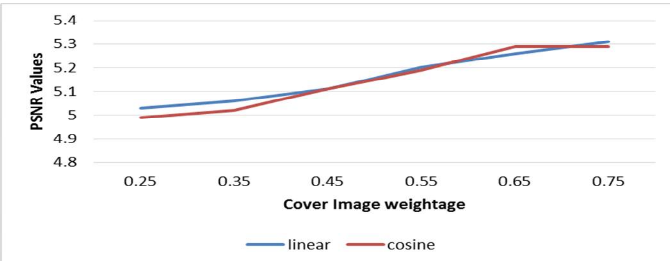
- Without any attack



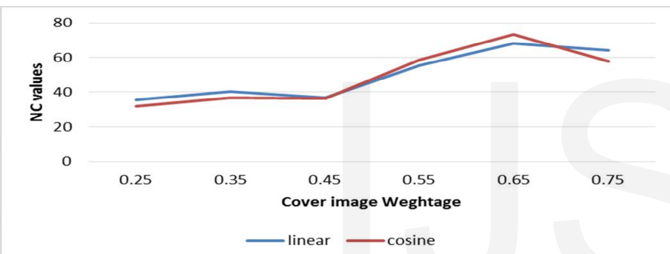


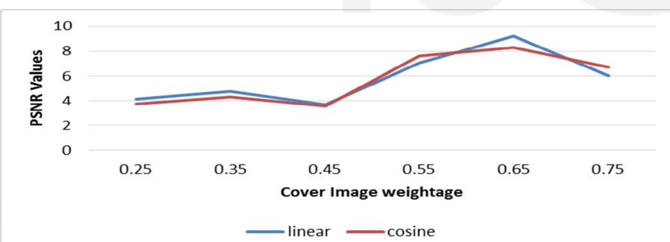
- After adding noise



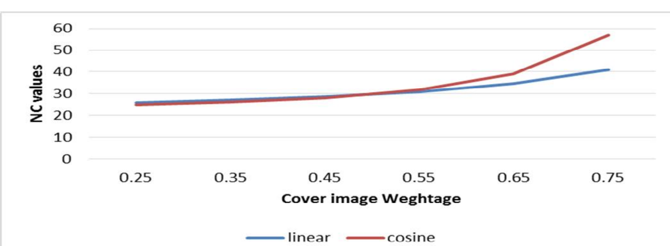


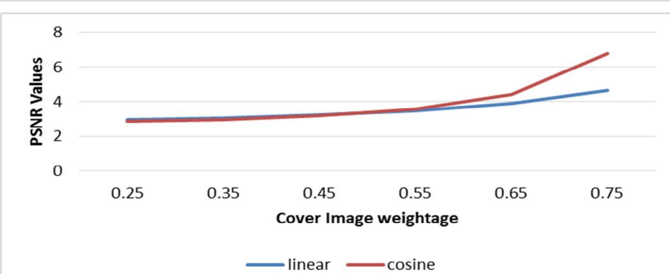
- After rotation





- After negation





6.2.2 Analysis

From above graphs of NC and PSNR and extracted watermark image snaps included in appendix, following results were derived.

When there was no attack on watermarked cover image, the extracted watermark was very good and highly recognizable. It was similar to the original watermark embedded. This is also reflected by corresponding NC and PSNR values. In this case, all two interpolation methods provided similar NC and PSNR but the Cosine method provided better PSNR values, as shown in above graphs.

On addition of salt & pepper noise on watermarked cover im-age, the extracted watermark image was recognizable in the range 25 % to 75% of cover im-age weight range. It was also reflected by the corre-sponding NC and PSNR values, which have sharp drop as compared to the values without any at-tack. These values were not good but visually the extract-ed watermark image was recognizable. In this case, the linear interpolation method provided better NC values whereas the Cosine interpolation method provided better PSNR values.

On rotating watermarked cover image by 45•, the extracted watermark was good and recognizable. The NC and PSNR were not so good but visually the extracted watermark was recognizable, as shown by the images included in appendix. In this case, the Cosine methods provided better NC and PSNR values as compared to other methods.

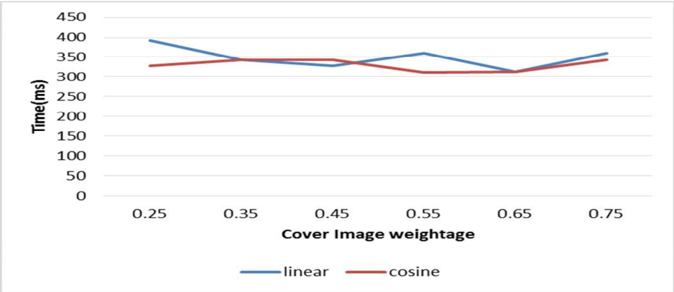
On negating the watermarked cover image, the extracted wa-termark was very good and much more recognizable, though the corresponding NC and PSNR values are not so good. It is also reflected by the images in the appendix. The negation has no much effect. All the methods provide similar meas-ure of performance parameter, as reflected by above graphs.

Above result were obtained after implementation of proposed algorithm. The main characteristics of digital image water-marking are imperceptibility and robustness. This SVD based watermarking technique was able to provide good impercep-tibility to the watermarked cover image but it was unable to provide robustness on some attack. Though the ex-tracted watermark was recognizable, the NC and PSNR values were low to consider good in some cases. To improve robustness, any frequency domain transform should be applied before performing SVD decomposition and then SVD should be ap-plied in the region where less attack of noise will be felt.

Among the interpolation method, Cosine method provided better result in most of the attacks. Though the parameters were not so good but it was good in performance as compared to other.

6.3 On the basis of computation time

6.3.1 Obtained data



6.3.2 Analysis

The computation time was similar to all two interpolation method. There was no distinction in performance of those methods on the basis of com-putation time. But above graphs showed some sharp rise on time used up. It is just because the CPU and memory of the computer might be busy on serving another process. Otherwise, all two methods com-putation time was similar.

7 Conclusion

Digital image watermarking is the process of em-bedding the watermark image in the cover image so that the embedded watermark image can be used to prove ownership and copy-right regarding issues. It has two main characteristics viz. im-perceptibility and robustness.
Singular Value Decomposition (SVD) technique has character-istics to resist changes on its singular values and make the system stable. This property of SVD is used in this study. Two interpolation methods are used individually to mark the wa-termark in the cover image.
As we have observed and discussed, “SVD based digital im-age watermarking using linear and cosine interpolation meth-od” is very good in providing imperceptibility to the water-marked cover image. The imperceptibility is possible because of the stability property of SVD. Though the extracted wa-termark was good enough to be recognized, the performance measuring parameters was not good enough to be considered in some cases. Hence for the robustness, the SVD based image watermarking needs another transformation before applying SVD decomposition.
The two interpolation methods used were linear and Cosine. The Cosine method provided better result and parameter val-ues as compared to other in-terpolation methods. Also time required by all two methods was similar. Hence, Cosine interpolation method can be used for adding watermark for better result.

8 Future enhancement and important achievement

From by using this paper one can make the water-marking module. S/he can implement watermarking method based on SVD and Cosine as it was justified in previous chapters. This is the major achievement of this study.

Anyone can improve this work by implementing frequency domain transformations like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) for improving ro-bustness of the process. S/he can study the same on color im-age. S/he can improve it by including metrics like proces-sor usage, memory usage etc. Also other interpolation tech-nique can be included.

It can also be implemented in Cloud. The valuable copyright digital image will be stored as a service in the cloud so that only the authenticated users can access and verify those imag-es. To elicit the re-searchers may implement it by using soft-ware as a service that run on distant computers in the cloud. Those services are owned and operated by others and that connect to users’ computers via the Internet and, usually, a web browser.

Using those services; one can sign up and rapidly start using innovative business apps. Apps and data are accessible from any connected computer. No data is lost if a remote computer breaks, as data is in the cloud. The service is able to dynami-cally scale to usage needs.

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