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Advance Robust Watermarking Of Compressed and Encrypted Digital Media

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Abstract: ***Due to rapid increase of internet these days has raised the worth of digital media all over the world. Digital watermarking is an application associated with copyright protection. Any digital object can be used as a carrier to carry information. If the information is related to object then it is known as a watermark which can be visible or invisible. Robustness is checked well by extracting original watermark perfectly without any degradation in the original image. But while embedding watermark into a cover image, there is a possibility of degradation in quality of original image. In this work, we introduce a blind watermarking scheme based on DWT and SVD. For providing the security, Blowfish encryption algorithm is used. Due to great developments in use of internet, multimedia data can be easily copy and distributed without owner's permission. Multimedia data includes images, audio and video. This poses a threat of unauthorized possession and usage of digital images. An additional threat is the illegal tampering and modification of digital images. Thus, the need arises for techniques to protect the copyright of digital material. Digital watermarking is one of the best solutions to avoid illegal copying, modifying and redistributing multimedia data. In digital watermarking watermark image is embedded into a cover image. By embedding watermark into the cover image the quality of cover image get degrade. This media data is often distributed in compressed and encrypted format and watermarking of these media data for copyright violation detection, proof of ownership, media authentication, sometimes need to be carried out in compressed-encrypted domain. Digital asset management is a system which handles data in compressed and encrypted format. A watermark should be embedded in such a way that it remains detectable as long as the perceptual quality of the digital content stays at an acceptable level***

Keywords: Software, Digital Media, watermarking, image, encryption

1. Introduction

In recent times, due to great developments in use of internet, multimedia data can be easily copy and distributed without owner's permission. Multimedia data includes images, audio and video. This poses a threat of unauthorized possession and usage of digital images. An additional threat is the illegal tampering and modification of digital images. Thus, the need arises for techniques to protect the copyright of digital material. Digital watermarking is one of the best solutions to avoid illegal copying, modifying and redistributing multimedia data. In digital watermarking watermark image is embedded into a cover image. By embedding watermark into the cover image the quality of cover image get degrade. This media data is often distributed in compressed and encrypted format and watermarking of these media data for copyright violation detection, proof of ownership, media authentication, sometimes need to be carried out in compressed-encrypted domain. Digital asset management is a system which handles data in compressed and encrypted format. A watermark should be embedded in such a way that it remains detectable as long as the perceptual quality of the digital content stays at an acceptable level [13].

A watermark is a recognizable image or pattern in paper that appears as various shades of lightness/darkness when viewed by transmitted light (or when viewed by reflected light, atop a dark background), caused by thickness or density variations in the paper. Watermarks have been used on postage stamps, currency, and other government documents to discourage counterfeiting. There are two main ways of producing watermarks in paper; the dandy roll process, and the more complex cylinder mould process.

Watermarks vary greatly in their visibility; while some are obvious on casual inspection, others require some study to pick out. Various aids have been developed, such as watermark fluid that wets the paper without damaging it. Watermarks are often used as security features of banknotes, passports, postage stamps, and other documents to prevent counterfeiting.

A watermark is very useful in the examination of paper because it can be used for dating, identifying sizes, mill trademarks and locations, and determining the quality of a sheet of paper. Encoding an identifying code into digitized music, video, picture, or other file is known as a digital watermark.

There are several digital watermarking techniques. These techniques can be classified into two types first is spatial domain techniques and second is frequency domain techniques. In spatial domain technique data is directly embed by modifying the pixel values of the original image. However, these techniques are hardly robust. In frequency domain technique the data is embed by modulating the coefficients of a properly chosen transform [2]. Watermarking in frequency domain is more secure and robust to various attacks.

The basic philosophy in majority of the transform domain watermarking schemes is to modify transform coefficients based on the bits in the watermark image. Most of the domain transformation watermarking schemes works with DCT and DWT. However, SVD is one of the most powerful numerical analysis technique and used in various applications. In SVD, singular values of cover image are calculated and these singular values are used to hide the watermark.

Encryption of multimedia products prevents an intruder from accessing the contents without a proper decryption key. But once the data is decrypted, it can be duplicated and distributed illegally. To enforce IP rights and to prevent illegal duplication, interpolation and distribution of multimedia data, Digital watermarking is an effective solution. Copyright protection, data authentication, covert communication and content identification can be achieved by Digital watermarking [1]. We propose to use a Blowfish encryption algorithm. No attack is known to be successful against Blowfish algorithm. It is suitable for applications where the key does not change often, like a communications link or an automatic file encryptor. It is significantly faster than most encryption algorithms when implemented on 32-bit microprocessors with large data caches [14].
Most common metrics used to evaluate image quality are peak-signal-to-noise ratio (PSNR), weighted PSNR (wPSNR), and the Watson just noticeable difference (JND), structural similarity index measure (SSIM). These metrics can help in achieving the tradeoff between the desired quality and the strength of watermark to be embedded [5].
Encryption of multimedia products prevents an intruder from accessing the contents without a proper decryption key. But once the data is decrypted, it can be duplicated and distributed illegally. To enforce IP rights and to prevent illegal duplication, interpolation and distribution of multimedia data, Digital watermarking is an effective solution. Copyright protection, data authentication, covert communication and content identification can be achieved by Digital watermarking [1].

It is propose to use a blind, secure and robust watermarking scheme based on SVD and DWT for JPEG images in which the watermark can be embedded in a predictable manner in compressed – encrypted byte stream.

Digital watermarking came to be in great demand when sharing information on the Internet became a usual practice. Sharing files online, you never know if someone uses them without your consent. To prevent unauthorized commerce use of your files, you can publish them to the web in the worst quality or don't publish anything worthwhile at all. It isn't a good way to solve the problem of unauthorized use, is it? So, you should look for more effective ways of copyright protection, such as digital watermarking.

A digital watermark is a pattern of bits inserted into a digital file - image, audio or video. Such messages usually carry copyright information of the file. Digital watermarking takes its name from watermarking of paper or money. But the main difference between them is that digital watermarks are supposed to be invisible or at least not changing the perception of original file, unlike paper watermarks, which are supposed to be somewhat visible.

In this paper, we propose a multipurpose watermarking scheme which can simultaneously achieve copyright protection and content authentication by hiding multipurpose watermarks at the same time. The validity of our method is based on simultaneous detection of the robust watermark and the fragile watermark. As a consequence, the order of hiding [22] is no longer an important issue. We propose to quantize the selected wavelet coefficients into masking threshold units. Then, the watermarks can be encoded by modulating the quantization result into either a right or a left masking threshold unit using cocktail watermarking [19]. In the meantime, the original quantization result can be recorded as the hidden watermark because it is the closest neighbor to the modulated quantization. Hence, the hidden watermark carries the information of the host image, which can be used to recover the host image with indistinguishable perceptual degradation. This information is very useful in calculating the detector responses about robust watermarking and fragile watermarking.

The major contribution of this work is twofold. First, a new oblivious watermark detection technique which is associated with our previously developed cocktail watermarking scheme is proposed. Since the good characteristics of cocktail watermarking are still maintained, the new oblivious scheme preserves high robustness for copyright protection. Second, the extent of modification can be estimated by comparing the hidden watermark with the extracted one. Under these circumstances, malicious tampering can be detected while some incidental manipulations can be tolerated. The remainder of this paper is organized as follows. In Section II, the no oblivious cocktail watermarking scheme is briefly reviewed. Then, multipurpose watermarking for image protection and authentication is described in detail in Section III. Analysis of our method with respect to fragile watermarking is conducted in Section IV. Finally, simulation results and conclusions are given in Section V and Section VI, respectively.

Adding a visible watermark is a common way of identifying images and protecting them from unauthorized use online. Learn how to create an effective watermark and apply it to your digital photos or art work.

A watermark is a visible embedded overlay on a digital photo consisting of text, a logo, or a copyright notice. The purpose of a watermark is to identify the work and discourage its unauthorized use. Though a visible watermark can't prevent unauthorized use, it makes it more difficult for those who may want to claim someone else's photo or art work as their own. Another type of watermark is the digital watermark, pioneered by Dig marc Corporation. Dig marc offers a service for embedding digital code into photos and other media that is undetectable during normal use, but enables tracking and identification of the media. visible watermark can be removed with a lot of time and patience, but generally not easily and not without leaving tell-tale signs behind. The collective opinion is that the kind of people that would steal images to claim as their own are acting out of laziness and would be unlikely to bother with trying to remove a well-placed watermark. Many of the people who take images are simply clueless about copyrights and they think anything on the Internet is free for the taking.
1) Compressed Domain Watermarking: A small modification in the compressed data may lead to a considerable deterioration in the quality of decoded image. Thus the position for watermark embedding has to be carefully identified in the com pressed data, so that the degradation in the perceptual quality of image i s minimal.

2) Encrypted Domain Watermarking and Watermark Re trieval : In an encrypted piece of content, changing even a single bit may lead to a random decryption, therefore the encryption should be such that the distortion due to embedding can be controlled to maintain the image quality. It should also be possible to detect the watermark correctly even after the content is decrypted. Also, the compression gain should not be lost as encryption may lead to cipher text expansion.

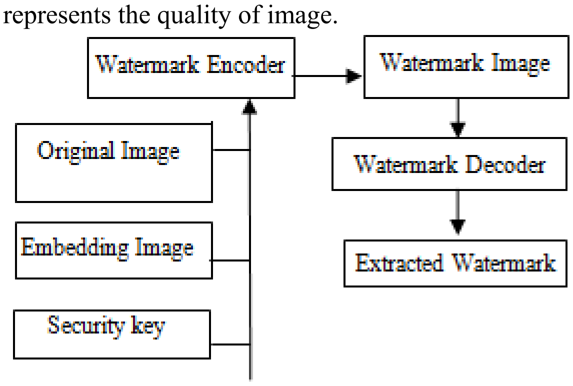
2. Present Work

Over the Internet due to a lack of security, images can be easily duplicated and distributed without the owner's consent. There are methods of embedding a watermark for preserving copyrights and eventually preserving security and data confidentiality. The problem with the existing systems is that it degrades the image quality at certain extends while embedding watermark. In case of any dispute during rights violation, content creator can prove ownership by recovering the watermark. Two most important prerequisites for an efficient watermarking scheme are robustness and security. Watermark must be robust and recoverable even if a part of content is altered by one or more attacks like compression, filtering, geometric distortions, resizing, etc.

To introduce an algorithm for invisible watermarking of compressed and encrypted digital media also to maintain the data security and confidentiality of particular digital media without compromising the quality of that object.

The review of literature explains in brief regarding work done by different authors in digital watermarking. In this project the first step is image compression in which image get compressed to reduce the size of image. Then, a compressed image is watermarked with watermark logo and secret key. Singular value decomposition algorithm is used to hide the watermark logo into cover image. DWT decomposition is used to decompose the image into four frequency bands such as LL, LH, HL, and HH. HH band of cover image is used to hide the watermark logo. Blowfish encryption algorithm is used for additional security to watermarked image.

Experimental results shows output of the system which includes compressed image, watermark image, encrypted image, histogram of images, level 1 DWT decomposition, level 4 DWT decomposition, and extracted watermark. For experiment, five images are taken to test the system under various attacks. PSNR values are also calculated which represents the quality of image.



3. Work Flow of Watermark Algorithm

3.1 Propose Methodology

Encryption Algorithm: Blowfish is a symmetric block cipher that encrypts data in 8- byte (64-bit) blocks. The algorithm has two parts, key expansion and data encryption. Key expansion consists of generating the initial contents of one array (the P-array), namely, eighteen 32-bit sub keys, and four arrays (the S boxes), each of size 256 by 32 bits, from a key of at most 448 bits (56 bytes). Blowfish also incorporated two exclusive-or operations to be performed after the 16 rounds and a swap operation. Blowfish can have a key that ranges from 32 to 448-bits. It is suitable and efficient for hardware implementation and no license is required. Blowfish is a cipher based on Feistel rounds. No attack is known to be successful against this. It is suitable for applications where the key does not change often, like a communications link or an automatic file encryptor. It is significantly faster than most encryption algorithms when implemented on 32-bit microprocessors with large data caches. Image encryption techniques try to convert an image to another one that is hard to understand. On the other hand, image decryption retrieves the original image from the encrypted one. Detailed description of Blowfish algorithm is given in below.

Encryption Process: Data image as a plaintext and the encryption key are two inputs of encryption process. In this case, original image data bit stream is divided into the blocks length of Blowfish algorithm. Image header is excluded to encrypt and the start of the bitmap pixel or array begins right after the header of the file. The byte elements of the array are stored in row order from left to right with each row representing one scan line of the image and the rows of the image are encrypted from top to bottom.

3.2 Decryption Process

The encrypted image is divided into the same block length of Blowfish algorithm from top to bottom. The first block is entered to the decryption function and the same encryption key is used to decrypt the image but the application of sub keys is reversed. The process of decryption is continued with other blocks of the image from top to bottom [4].

a) Embedding algorithm

1. Apply DWT decomposition and decompose cover image into four sub-bands: LL, HL, LH, and HH.
2. Apply SVD to HH band.
   $H = U_H \times S_H \times V_w^T$
3. Watermark W is decomposed using SVD
   $W = U_w \times S_w \times V_w^T$
4. Replace the singular values of the HH band with the singular values of the watermark.
5. Apply inverse SVD to obtain the modified HH band.
   $H' = U_H \times S_w \times V_H^T$
6. Apply inverse DWT to produce the watermarked cover image.

b) Extraction algorithm

1. Apply DWT decomposition and decompose the watermarked image into four sub-bands: LL, HL, LH, and HH.
2. Apply SVD to HH band.
   $H = U_H \times S_H \times V_H^T$
3. Extract the singular values from HH band.
4. Construct the watermark using singular values and orthogonal matrices U_w and V_w obtained using SVD of original watermark.
   $W_E = U_w \times S_H \times V_w^T$

c) Signature embedding

1. Generate the signature of N bits for the U and V matrices of watermark.
2. Using DWT decomposition, decompose the cover image into 4 sub-bands: LL, HL, LH, and HH. Further decompose LL band to the 4th level.
3. Modify LL4 and HH4 band coefficients with the bits of signature.

d) Signature extraction

1. Using DWT decomposition, decompose the watermarked image into 4 sub-bands: LL, HL, LH, and HH with help of DWT decomposition, decompose LL band to the 4th level.
2. Extract the signature from LL4 and HH4 band.
3. Generate signature using U and V matrices of the original watermark at the receiver and compare it with extracted signature. If they match, authenticate U and V matrices and use them in watermark estimation.

3.3 Blowfish Algorithm

The data transformation process for Pocket Brief uses the Blowfish Algorithm for Encryption and Decryption, respectively. The details and working of the algorithm are given below.

Blowfish is a symmetric block cipher that can be effectively used for encryption and safeguarding of data. It takes a variable-length key, from 32 bits to 448 bits, making it ideal for securing data. Blowfish was designed in 1993 by Bruce Schneier as a fast, free alternative to existing encryption algorithms. Blowfish is unpatented and license-free, and is available free for all uses. Blowfish Algorithm is a Feistel Network, iterating a simple encryption function 16 times. The block size is 64 bits, and the key can be any length up to 448 bits. Although there is a complex initialization phase required before any encryption can take place, the actual encryption of data is very efficient on large microprocessors. Blowfish is a variable-length key block cipher. It is suitable for applications where the key does not change often, like a communications link or an automatic file encryptor. It is significantly faster than most encryption algorithms when implemented on 32-bit microprocessors with large data caches.

3.4 Algorithm

Blowfish is a variable-length key, 64-bit block cipher. The algorithm consists of two parts: a key-expansion part and a data- encryption part. Key expansion converts a key of at most 448 bits into several subkey arrays totaling 4168 bytes. Data encryption occurs via a 16-round Feistel network. Each round consists of a key dependent permutation, and a key- and data-dependent substitution. All operations are XORs and additions on 32-bit words. The only additional operations are four indexed array data lookups per round.

Subkeys

Blowfish uses a large number of subkeys. These keys must be precomputed before any data encryption or decryption. The P-array consists of 18 32-bit subkeys:
P1, P2,..., P18.
There are four 32-bit S-boxes with 256 entries each:
S1,0, S1,1,..., S1,255;
S2,0, S2,1,..,, S2,255;
S3,0, S3,1,..., S3,255;
S4,0, S4,1,..,, S4,255

The subkeys are calculated using the Blowfish algorithm:

1. Initialize first the P-array and then the four S-boxes, in order, with a fixed string. This string consists of the hexadecimal digits of pi (less the initial 3): P1 = 0x243f6a88, P2 = 0x85a308d3, P3 = 0x13198a2e, P4 = 0x03707344, etc.
2. XOR P1 with the first 32 bits of the key, XOR P2 with the second 32-bits of the key, and so on for all bits of the key (possibly up to P14). Repeatedly cycle through the key bits until the entire P-array has been XORed with key bits. (For every short key, there is at least one equivalent longer key; for example, if A is a 64-bit key, then AA, AAA, etc., are equivalent keys.)
3. Encrypt the all-zero string with the Blowfish algorithm, using the subkeys described in steps (1) and (2).
4. Replace P1 and P2 with the output of step (3).
5. Encrypt the output of step (3) using the Blowfish algorithm with the modified subkeys.
6. Replace P3 and P4 with the output of step (5).
7. Continue the process, replacing all entries of the P array, and then all four S-boxes in order, with the output of the continuously changing Blowfish algorithm.

Encryption

Blowfish has 16 rounds.
The input is a 64-bit data element, x.
Divide x into two 32-bit halves: xL, xR.
Then, for i = 1 to 16:
xL = xL XOR Pi
xR = F(xL) XOR xR
Swap xL and xR
After the sixteenth round, swap xL and xR again to undo the last swap.
Then, xR = xR XOR P17 and xL = xL XOR P18.
Finally, recombine xL and xR to get the ciphertext.

4. Singular Value Decomposition (SVD)

Most tutorials on complex topics are apparently written by very smart people whose goal is to use as little space as possible and who assume that their readers already know almost as much as the author does. This tutorial's not like

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that. It's more a manifestivus for the rest of us. It's about the mechanics of singular value decomposition, especially as it relates to some techniques in natural language processing. It's written by someone who knew zilch about singular value decomposition or any of the underlying math before he started writing it, and knows barely more than that now. Accordingly, it's a bit long on the background part, and a bit short on the truly explanatory part, but hopefully it contains all the information necessary for someone who's never heard of singular value decomposition before to be able to do it. SVD is one of the most useful tools in linear algebra with several applications in image compression, watermarking, and other signal processing areas.

SVD of matrix A can be defined as $\mathbf{A = U{*}S{*}V^T}$, where U and V are the orthogonal matrices and S is a diagonal matrix. Diagonal elements of S are the singular values and they satisfy the following property

$s(1,1) > s(2,2) > s(3,3) > \ldots\ldots\ldots\ldots > s(n,n)$.

Let's say we have a matrix A with m rows and n columns, with rank r and $r \le n \le m$. Then the A can be factorized into three matrices:

$A = USV^T$

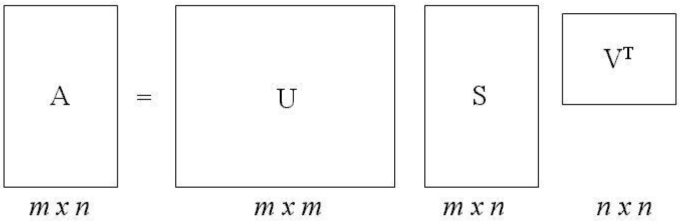


Figure: Illustration of Factoring A to USV^T

Where Matrix U is an m × m orthogonal matrix

$U = [\, u_1, u_2, \ldots u_r, u_{r+1}, \ldots, u_m \,]$

column vectors u_i , for i = 1, 2, …, m, form an orthonormal set:

$$u_i^T u_j = \delta_{ij} \begin{cases} 1 \ldots i = j \\ 0 \ldots i \ne j \end{cases}$$

And matrix V is an n × n orthogonal matrix

$V = [\, v_1, v_2, \ldots v_r, v_{r+1}, \ldots, v_n \,]$

column vectors $\mathbf{v_i}$ for i = 1, 2, …, n, form an orthogormal set:

$$v_i^T v_j = \delta_{ij} = \begin{cases} 1 \ldots i = j \\ 0 \ldots i \ne j \end{cases}$$

Here, S is an m × n diagonal matrix with singular values (SV) on the diagonal. The matrix S can be showed in following

$$S = \begin{bmatrix} \sigma(1) & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & \sigma(2) & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma(r) & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & \sigma(r+1) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & \cdots & \sigma(n) \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \end{bmatrix}$$

For i = 1, 2, …, n, **i** s are called Singular Values (SV) of matrix A. It can be proved that

$\sigma_1 \ge \sigma_2 \ge \ldots \ge \sigma_r > 0$ and $\sigma_{r+1} = \sigma_{r+2} = \ldots = \sigma_N = 0$.

For i = 1, 2, …, n, σi are called Singular Values (SVs) of matrix A. The v_i 's and u_i 's are called right and left singular vectors of A.

Properties of the SVD:

There are many properties and attributes of SVD; here we just present parts of the properties that we used in this project.

1. The singular value $\sigma_1, \sigma_2, \ldots \sigma_n$ are unique, however, the matrices U and V are not unique;
2. Since $A^T A = VS^T SV^T$, so V diagonalizes $A^T A$, it follows that the $\mathbf{v}_j$'s are the eigenvector of $A^T A$.
3. Since $AA^T = USS^T U^T$, so it follows that U diagonalizes AA^T and that the u_i 's are the eigen vectors of AA^T.
4. A has rank of r then $\mathbf{v}_j, \mathbf{v}_j, \ldots, \mathbf{v}_r$ form an orthonormal basis for range space of, R (A^T), and $\mathbf{u}_j, \mathbf{u}_j, \ldots, \mathbf{u}_r$ form an orthonormal basis for .range space A, R(A).
5. The rank of matrix A is equal to the number of its nonzero singular values.

5. Result Analysis for Test Images

Table 1: Test result for robustness against attacks

Attack	*Image1 PSNR(dB)*	*Image2 PSNR(dB)*	*Image5 PSNR(dB)*
Gaussian Attack	38.1582	37.4074	39.4436
salt & pepper Attack	36.7483	36.6887	38.9567

Table 2: PSNR of watermarked test images

Image	Image1	Image2	Image3	Image4	Image5
PSNR(dB)	40.6136	39.7130	40.6790	39.3388	40.5136
Correlation coefficients	0.9994	0.9995	0.9996	0.9994	0.9991

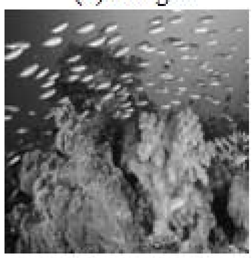
Table 3: Singular values of HH frequency band of different images

Images	Max singular value	Min singular value
Image1	134	0
Image2	136	0
Image3	139	0
Image4	132	0
Image5	140	0

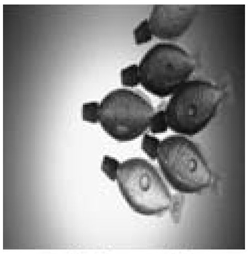
(a) Image1

(b) Image2

(c) Image 3



(d) Image 4



(e) Image 5

"Table1" shows the watermarked image after attacks. "Fig. 5" shows different test images. "Table 3" shows singular values of the HH band of different test images. To check perceptual similarity between original and watermarked image, Peak-signal-to-noise ratio (PSNR) and correlation coefficient are used as a metric. The PSNR (in dB) of the watermarked images are shown in "Table 2". Correlation coefficient between original and watermarked image is also very close to 1, indicating excellent perceptual fidelity.

6. Conclusion and Future Scope

6.1 Conclusions

Over the internet due to lack of security images can be easily duplicated and distributed without owner permission. Therefore, Digital watermarking is one of the solutions for authentication, copy control and right management of digital media. A digital image is category under digital media. In watermarking, watermark logo get hide into cover image. But while embedding watermark into a cover image, there is a possibility of degradation in quality of original image. Robustness is checked well by extracting original watermark perfectly without any degradation in the original image. Digital asset management system (DAMS) handles almost compressed and encrypted media data. It is possible to watermark these compressed-encrypted media for ownership declaration or copyright management. For encryption we use Blowfish encryption algorithm. It is propose to use a blind watermarking scheme based on DWT and SVD. The main goal is to develop an algorithm to maintain data security and confidentiality of digital media without compromising the quality of that object. The proposed Signature based authentication mechanism addresses the issue of authentication and security which most of the existing DWT & SVD based methods fail to handle. The used algorithm is simple to implement as it is directly performed in the compressed encrypted domain as it does not require decryption or de-compression of the image. In compression it is concluded that as increase in decomposition level more the image get compressed but results in loss of image quality. This technique also preserves the confidentiality of content as embedding is done on encrypted images.

6.2 Future Scope

Future work consists of two aspects as given below:
1. To work on more complex image such as vary large size 2D image or 3D images with SVD technique for image compression.
2. Deeply to study and investigate the roles of singular values and singular vectors in image processing.

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