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A DWT based reversible watermarking for lossless recovery

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Abstract— A novel method for generic visible watermarking with a capability of lossless video recovery is proposed. The method is based on the use of deterministic one-to-one compound mappings of frame pixel values for overlaying a variety of visible watermarks of arbitrary sizes on cover videos. The compound mappings are proved to be reversible, which allows for lossless recovery of original video from watermarked video. The mappings may be adjusted to yield pixel values close to those of desired visible watermarks. The visible watermarks, the opaque monochrome watermark, are embedded as applications of the proposed generic approach. A DWT (Discrete Wavelet Transform) has been proposed to provide effective robustness for lossless recovery of video after applying DWT. Security protection measures by parameter and mapping randomizations have also been proposed to deter attackers on illicit image recoveries. Experimental results demonstrating the effectiveness of the proposed approach are also included.

Index Terms—Digital information, embedding algorithm, frames, one-one compound mapping, pixel values, PSNR, video watermarking.

1 Introduction

Video watermarking refers to embedding watermarks in a video sequence in order to protect the video from illegal copying and identify manipulations. A variety of robust and fragile video watermarking methods have been proposed to solve the illegal copying and proof of ownership problems[2].The embedded watermark is expected to be secure to various kinds of malicious and non-malicious attacks to some extent, provided that the manipulated content is still valuable in terms of commercial significance or perceptual quality. Lossless recovery is important in many applications where serious concerns about video quality arise. Some examples include forensics, medical image analysis, historical art imaging, or military applications [1], [4]. As to lossless visible watermarking, the most common approach is to embed a monochrome watermark using deterministic and reversible mappings of pixel values or DCT coefficients in the watermark region. One of the most difficult problems in digital video watermarking is watermark recovery in the presence of geometric attacks like frame shift, cropping, scaling and rotation. Video watermarking approaches can be classified into two main categories based on the method of hiding watermark bits in the host video. The two categories are: Spatial domain watermarking where embedding and detection of watermark are performed by directly manipulating the pixel intensity values of the video frame. Transform domain techniques, on the other hand, alter spatial pixel values of the host video according to a pre-determined transform and are more robust than spatial domain techniques since they disperse the watermark in the spatial domain of the video frame making it difficult to remove the watermark through malicious attacks like cropping, scaling, rotations and geometrical attacks. The commonly used transform domain techniques are Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT), and the Discrete Wavelet Transform (DWT)[7],[8],[9].This paper presents a novel approach of how the visible watermarks are embedded into the MPEG video and obtaining the capability of lossless recovery of original video using DWT by dividing the video into sequence of frames .Many surveys on digital video watermarking has been conducted in the previous researches[3]. Some of the video watermarking technique like SVD(Singular Value Decomposition) has been proposed to protect against the illegal attach for video[5] .Discrete Cosine Transform with various quantization level are also carried out to provide secure to the video[6].

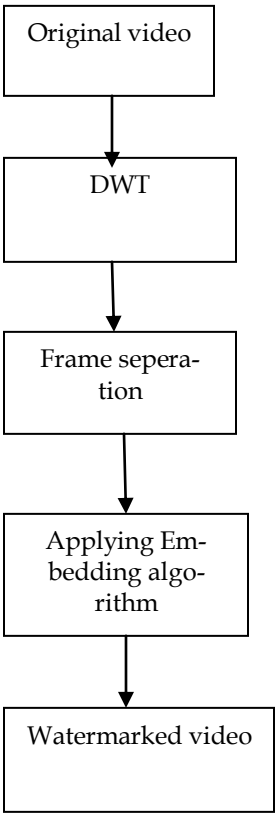

Fig1.block diagram of digital watermarking

As to lossless visible watermarking, the most common approach is to embed a monochrome watermark using deterministic and reversible mappings of pixel values or DCT coefficients in the watermark region. DWT offers better energy compaction than DCT without any blocking artifact. DWT splits component into numerous frequency bands called sub bands another approach is to rotate consecutive watermark pixels to embed a visible watermark. One advantage of these approaches is that watermarks of arbitrary sizes can be embedded into any host image. However, only binary visible watermarks can be embedded using these approaches, which is too restrictive since most company logos are colorful. In this paper, a new method for lossless visible watermarking is proposed by using appropriate compound mappings that allow mapped values to be controllable. The mappings are proved to be reversible and more specific compound mappings are also created and proved to be able to yield visually more distinctive visible watermarks in the watermarked video.

2 DWT (Discrete Wavelet Transform)

DWT is the discrete variant of the wavelet transform. Wavelet transform represents a valid alternative to the cosine transform used in standard MPEG. The DWT of video is a transform based on the tree structure with D levels that can be implemented by using an appropriate bank of filters .Essentially it is possible to follow two strategies that differ from each other basically because of the criterion used to extract strings of image (frame) samples to be elaborated by the bank of filters. The first solution consists of generating the string by queuing frame lines and then executing decomposition on D levels; after this operation, we generate D strings by queuing the columns from the found sub-images and decomposition for each string is applied. The resulting decomposition, in the simplified version extended up to the third level, is shown in figure 2.

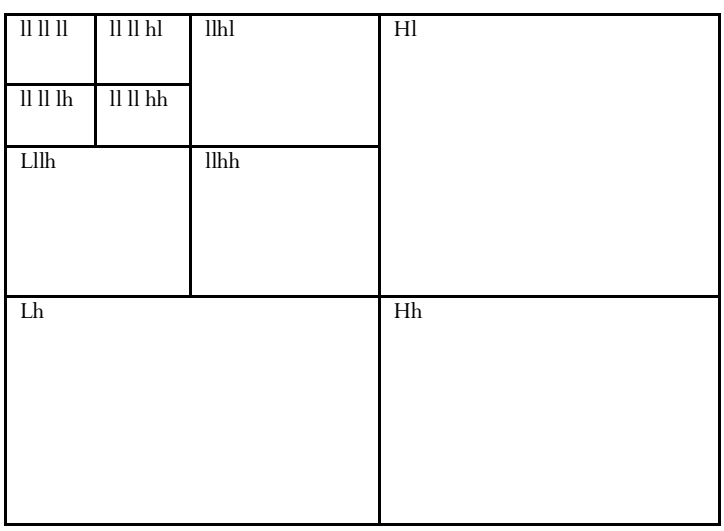

Fig.2- 2D -DWT

3 Proposed new approach to lossless visible waetrmarking

In this section, the proposed approach to lossless reversible visible watermarking is described, based on which appropriate one-to-one compound mapping scan is designed for embedding different types of visible watermarks into frames. The original video can be recovered losslessly from a resulting watermarked image by using the corresponding reverse mappings.

3.1 one-one compound mapping

First, we propose a generic one-to-one compound mapping for converting a set of numerical valuesP={p1,p2,…pM},Q={q1,q2,…qM}, such that the mapping pi, qi for all i=1,2,3..M is reversible. Here, for the copyright protection applications investigated in this study, all the values pi and qi are frame pixel values (grayscale or color values). The compound mapping f is governed by a one-to-one function Fx with one parameter x=a or b in the following way.

$q=f(p)=Fb^{-1}(Fa(P))$ ---------- (1)

Where Fx^{-1} is the inverse of Fx which, by

The one-to-one property, leads to the fact that if Fa (p) =P, then Fa (p′) =p for all values of a and b. On the otherhand Fa (p), and Fb (p) generally are set to be unequal if a≠b. The compound mapping described by (1) is indeed reversible, that is p can be derived exactly from q using the following formula:

$p = f^{-1}(q) = Fa^{-1}(Fb(q))$ --------- (2)

As proved.

Lemma 1 (Reversibility of compound Mapping):

If $q= Fb^{-1}(Fa(p))$ for any one-to-one function FX with a parameter x, then $p= Fa^{-1} Fb^{-1}(q))$ for any values of a, b, p and q.

Proof: substituting (1) into $Fa^{-1}(Fb(q))$, We get $Fa^{-1}(Fb(q)) = Fa^{-1}(Fb(Fb^{-1}(Fa(p))))$ By regarding Fa(p) as a value c, the right-hand sidebecomes

$Fa^{-1}(Fb(Fb^{-1}(c)))$

Which after Fb and Fb^{-1} are cancelled out, becomes $Fa^{-1}(c)$.

But $Fa^{-1}(c) = Fa^{-1}(Fa(p))$

This is just p after Fa and Fa-1 are cancelled

Out. That is, we have

$p= Fa^{-1}(Fb(q))$

As an example, if Fx (p) =xp+d, then

$Fx^{-1}(p`)=(p`- d)/x$

Where ξ is small value.

$Thusq=Fb^{-1}(Fa(p)) =Fb^{-1}(ap+d) = (ap+d-d)/b=ap/b$

And so, we have

$Fa^{-1}(Fb(q))=Fa^{-1}(b(ap/b)+d)=Fa^{-1}(ap+d)=[((ap+d)-d)-d)/a]=(ap/a)=p$

As expected by Lemma1

3.2 lossless visible watermarking

To obtain the lossless visible watermarking the embedding is reversible, that is, the watermark can be removed to recover the original video lossless. For this aim, a preliminary lemma is first described as follows .Lemma 2 (Preference of com-

pound Mapped Value): It is possible to use the compound mapping

$$q=F\,b^{-1}(Fa\,(p))$$

.to converts a numerical value p to another revalue close to a preferred value l.

Proof: Let Fx (p) =p-x where x is the parameter for F.

Then Fx-1 (p`) =p`+ x. Also let a=p- ξ and b=1Then the compound mapping

$Fb^{-1}(Fa(p))$ of p yield q as

$q=Fb^{-1}(Fa(p))=Fb^{-1}(p-a)=Fb^{-1}(\xi)$

$= \xi + b = \xi + l$

This means that the value q is close to the preferred value l

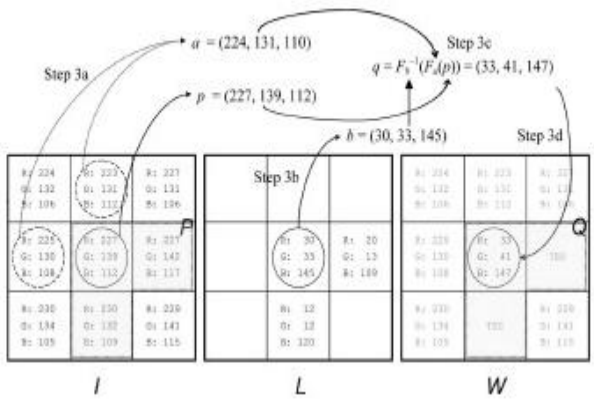

Fig.3. Illustration of mapping the center pixel of a 3x3 frame pixel values of several frames using DWT where I(frame original),L(watermark),W(watermarked frame) using algorithm 1

The above lemma relies on two assumptions. The first is that 'a' is close to 'p', or equivalently, that a=p- ξ. The reason why we derive the above lemma for a=p- ξ instead of for a=p is that in the reverse mapping we want to recover p from q without knowing p, which is a requirement in the application of reversible visible watermarking investigated in this studies. Although the value of p cannot be known in advance for such applications, it can usually be estimated.The second assumption is that Fx(p) yield a small value if x and p are close. Though the basic difference function Fx(p)=p-x used in the above proof satisfies this requirement for most cases, there is a possible problem where the mapped value of a,b and p. For example when a=255, b=255 and p=253, wehave q=255-253+255=257 > 255. It is possible to use the standard modulo technique (ie. taking q=257mode256 =1) to solve this issue, however, such a technique will make q far from the desired target value of b, which is 255. Nevertheless we will show in section 3 that using such a standard modulo function Fx (p) = (p-x) mode256 can still yield reasonable experimental results. Furthermore, we show a more sophisticated one-to-one function that is free from such a wrap around problem.By satisfying the above two requirement, the compound mapping yields a value q that is close to the desired value l. the following theorem prove about the desired lossless reversible visible watermarking.

3.3 Theorem

There exist one-to-one compound mappings for use to embed into a given frame I a visible watermark Q whose pixel values are close to those of a given watermark L, such that the original video can be recovered from Q losslessly.

Proof: This is a consequence of Lemmas 1 and 2 after regarding the individual pixel values in, and Q respectively as those of p, l and q mentioned in Lemma 2. And it is clear by Lemma 1 that the value p can be recovered losslessly from the mapped value q which is derived in Lemma 2.The above discussions are valid for embedding a watermark in a grayscale frame. The spatial and transform domains are two common methods for image watermarking. Embedding the watermark into the transform-domain generally helps to increase the imperceptibility, security, and robustness. Therefore, at present, most of image watermarking methods are in the transform domain, where DFT, DCT, DWT are three main transform methods used. The resulting visible watermark is the composite result of the color channels.Based on the Theorem 1 the proposed generic lossless reversible visible watermarking scheme with a given frame I and a watermark L as input is described as an algorithm as follows.

Algorithm:

Visible Watermark Embedding

Input: an frames I and a watermark L

Output: watermarked video W

1) Select a set of P pixels from 'I' where L is to be embedded and call P a watermarking area.

2) Denote the set of pixels corresponding to P in Wby Q.

3) For each pixel X with value p in P, denote the corresponding pixel in Q as Z and the value of the corresponding pixel Y in L as l and the conduct thefollowing steps:

a) Apply an estimation technique to derive a to be a value close to b using the value of the neighboring pixels of X

b) Set 'b' to be the value 'l'.

c) Map 'p' to a new value $q=Fb^{-1}$ (Fa (p)).

d) Set the value of Z to be q.

4) Set the value of each remaining pixel in W, which is outside the region P, to be equal to that of the corresponding pixel in 'I'. The corresponding watermark removal process for a watermarked image Wgenerated by Algorithm 1 is described as follows.

3.4 Security Considerations

As mentioned previously, although we want legitimate users to be able to recover the original video from a watermarked one, we do not want an attacker to be able to do the same. Here in, we propose some security protection measures against illicit recoveries of original videos. First, we make the parameters (pixel values) and in the above algorithms to be dependent on certain secret keys that are known only by the creator of the watermarked image and the intended receivers. One simple technique to achieve this is to use a secret key to

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generate a pseudorandom sequence of numerical values and add them to either or both of a and b for the pixels in the watermarking area. This technique is here in after referred to as parameter randomization.Another way of security protection is to make the choices of the positions for the pixels to be denoted as X1 and X2 with values p1 and p2 respectively dependent on a secret key. Let the two pixels be denoted as X1 and X2 with values p1 and p2 respectively.

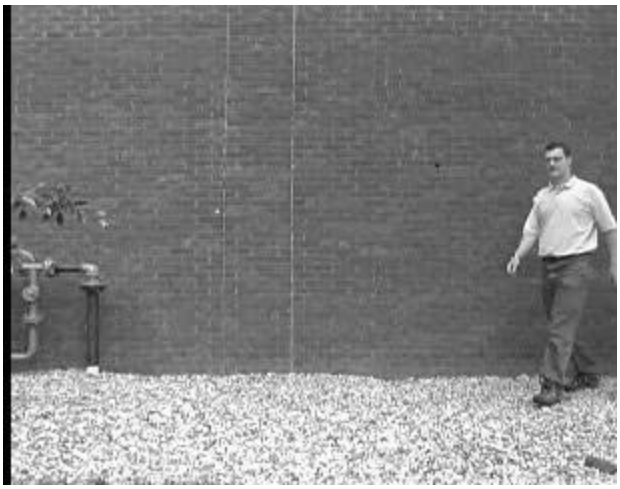

Fig .4 frame 1 after applying DWT

Fig.5 frame 13 after applying DWT.

The color estimation a1 and a2 corresponding to X1 and X2 are respectively, are individually derived as before using their respective neighbors. The parameters b1 and b2 are set to be the values l1 and l2 of the respective watermark pixels Y1and Y2 .Then, instead of setting the values of the watermarked pixels Z1 and Z2 to beq1= $Fb1^{-1}$ (fa1(p1)) and q2= Fb_2^{-1} (fa2(p2))as before, we swap the parameters and setq1= $Fb1^{-1}$ (fa2(p2)) and q2= Fb_2^{-1} (fa1(p1))and This parameter exchange does not affect the effectiveness of lossless recoverability, because we can now recover the original pixel values by the following compound mappings: and We will refer to this technique in the equal as mapping randomization. We may also combine this technique with the above mentioned parameter randomization technique to enhance the security further.

Fig.6 frame 40 after applying DWT

Fig.7 frame 52 after applying DWT.

Fig. 8 frame 68 after applying DWT.

Last, the position in the frame where a watermark is embedded affects the resilience of the watermarked video against illicit video recovery attempts. In more detail, if the watermark is embedded in a smooth region of the frame, an attacker can simply fill the region with the background color to remove the watermark irrespective of the watermarking technique used. To counter this problem, an appropriate position should be chosen, using for example, the adaptive positioning technique [10].

Fig .9 frame 80 after applying DWT.

Fig .10 watermarks that to be embedded.

Fig.11 digramatic representation of watermarked video.

The above digrams fromfig.4- fig.11 represents how the original video is divided into different frame after applying DWT.Generally the sample video taken for operation isMPEG video and from the sample the video is divided into 80 frames.

4 Conclusion

In this Paper a new method for reversible visible watermarking with lossless video recovery capability has been proposed.By the use of one-one compound mapping and applying DWT operation on the video the PSNR(Peak to noise Signal Ratio) value obtained is 39db.When compared to other spatial domain technique which applies for video to be watermarked this technique works better based on time and robustness on the video.The results for previous operations like DCT, the PSNR is 29db and for compressed DCT the PSNR value is 33db approximately.

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