International Journal of Engineering Research and Development
e-ISSN: 2278-067X, **p**-ISSN : 2278-800X, www.ijerd.com
Volume 4, Issue 9 (November 2012), PP. 27-35

Lossless Visible Watermarking Using Compound Mapping

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Abstract—A compound mapping method for visible watermarking with a capability of lossless image recovery is proposed. The method is based on the use of deterministic one-to-one compound mappings of image pixel values for overlaying a variety of visible watermarks of arbitrary sizes on cover images. The compound mappings are proved to be reversible, which allows for lossless recovery of original images from watermarked images. The mappings may be adjusted to yield pixel values close to those of desired visible watermarks. Different types of visible watermarks, including opaque monochrome and translucent full color ones, are embedded as applications of the proposed generic approach. Security protection also been proposed to deter attackers from illicit image recoveries. Experimental results demonstrating the effectiveness of the proposed approach are also included.

Index Terms—Lossless reversible visible watermarking ,Compound mapping, translucent watermark,PSNR.

I. INTRODUCTION

The advance of computer technologies and the proliferation of the Internet have made reproduction and distribution of digital information easier than ever before. Copyright protection of intellectual properties has, therefore, become an important topic. One way for copyright protection is digital watermarking [1]–[7], which means embedding of certain specific information about the copyright holder (company logos, ownership descriptions, etc.) into the media to be protected. Digital watermarking methods for images are usually categorized into two types: invisible and visible. The first type aims to embed copyright information imperceptibly into host media such that in cases of copyright infringements, the hidden information can be retrieved to identify the ownership of the protected host. It is important for the watermarked image to be resistant to common image operations to ensure that the hidden information is still retrievable after such alterations. Methods of the second type, on the other hand, yield visible watermarks which are generally clearly visible after common image operations are applied. In addition, visible watermarks convey ownership information directly on the media and can deter attempts of copyright violations. Embedding of watermarks, either visible or invisible, degrade the quality of the host media in general. A group of techniques, named reversible watermarking [8]–[19], allow legitimate users to remove the embedded watermark and restore the original content as needed. However, not all reversible watermarking techniques guarantee lossless image recovery, which means that the recovered image is identical to the original, pixel by pixel. Lossless recovery is important in many applications where serious concerns about image quality arise. Some examples include forensics, medical image analysis, historical art imaging, or military applications. Compared with their invisible counterparts, there are relatively few mentions of lossless visible watermarking in the literature. Several lossless invisible watermarking techniques have been proposed in the past. The most common approach is to compress a portion of the original host and then embed the compresseddata together with the intended payload into the host [5], [13]–[15]. Another approach is to superimpose the spread-spectrum signal of the payload on the host so that the signal is detectable and removable [3]. A third approach is to manipulate a group of pixels as a unit to embed a bit of information [16], [17]. Although one may use lossless invisible techniques to embed removable visible watermarks [11], [18], the low embedding capacitiesof these techniques hinder the possibility of implanting large-sized visible watermarks into host media. 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 [6], [9], [19]. Another approach is to rotate consecutive watermark pixels to embed a visible watermark [19]. 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 for lossless recovery of the original image. The approach is generic, leading to the possibility of embedding different types of visible watermarks into cover images. Two applications of the proposed method are demonstrated, where opaque monochrome watermarks and no uniformly translucent full-color ones are respectively embedded into color image More specific compound mappings are also created and proved to be able to yield visually more distinctive visible watermarks in the watermarked image. To the best knowledge of the authors, this is the first method ever proposed for embedding removable translucent full-color watermarks which provide better advertising effects than traditional monochrome ones. In the remainder of this paper, the proposed method for deriving one-to-one compound mappings is described in Section II. Related lemmas and theorems are also proved and security protection measures described. Applications of the proposed method for embedding opaque monochrome and translucent color watermarks into color images are described in Sections III and IV, respectively. In Section V, the specific compound mapping for yielding more distinctive visible watermarks is described. In Section VI, experimental results are presented to demonstrate the effectiveness of the proposed method. Finally, a conclusion with some suggestions for future work is included in Section VII.

II. PROPOSED NEW APPROACH TO LOSSLESS VISIBLE WATERMARKING

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

A. Reversible One-to-One Compound Mapping

First, we propose a one-to-one compound mapping f for converting a set of numerical values A={a_1,a_2,…..a_N} to another set B={b_1,b_2,….b_N} such that the respective mapping from a_i to $b_i$for all i=1,2,…….N is reversible.Here, for the copyright protection applications investigated in this study, all the values $a_i$and $b_i$are image pixel values (grayscale or color values). The compound mapping $f$is governedby a one-to-one function $G_x$with one parameter x=p or q in the following way

b=$g(a)$=$G_q^{-1}(G_p(a))$ (1)

Where $G_x^{-1}$is the inverse $G_x$which,by the one-to-one property, leads to the fact that if $G_p(a)$=a', then $G_p^{-1}(a')$ =a for all values of p and a On the other hand,$G_p(a)$ and $G_q(a)$ generally are set to be unequal if $p \neq q$.

The compound mapping described by (1) is indeed *reversible*, that is, a can be derived exactly from b using the following formula:

a=$g^{-1}(b)$=$G_p^{-1}(G_q(b))$ (2)

as proved below.

Babby1 (Reversibility of Compound Mapping):Ifb=$G_q^{-1}(G_p(a))$ for any one-to-one function $G_x$with a parameter x, then a=$G_p^{-1}(G_q(b))$ for any values of p,q,$a$and b

Proof: Substituting (1) into $G_p^{-1}(G_q(b))$, we get

$G_p^{-1}(G_q(b))$ =$G_p^{-1}(G_q(G_q^{-1}(G_p(a)))$

By regarding $G_p(a)$ as a value r, the right-hand side becomes $G_p^{-1}(G_q(G_q^{-1}(r)))$, which, after $G_q$and G_q^{-1} are cancelled out, becomes $G_p^{-1}(r)$. But $G_p^{-1}(r)$=$G_p^{-1}(G_p(a))$, which is just a after $G_p$and G_q^{-1} are cancelled out. That is, we have proved a=$G_p^{-1}(G_q(b))$.

As an example, if $G_x(a) = xa + s$, then $G_x^{-1}(a')$=(a'- s)/x. Thus$b$=$g(a)$=$G_q^{-1}(G_p(a))$=$G_q^{-1}(pa+s)$

=(pa+s-s)/q=pa/s

and so, we have

$G_p^{-1}(G_q(b))$=G_p^{-1}(q(pa/q)+s)=G_p^{-1}(pa+s)

=[((pa+s)-s)/p]=(pa/q)=a

as expected by Baby 1.

B. Lossless Visible Watermarking Scheme

Based on Baby1, we will now derive the proposed lossless visible watermarking scheme in the form of a class of one-to-one compound mappings, which can be used to embed a variety of visible watermarksinto images. The embedding is reversible, that is, the watermark can be removed to recover the original image losslessly. For this aim, a preliminary lemma is first described as follows.Baby2 (Preference of Compound-Mapped Value): It is possible to use the compound mapping b=$G_q^{-1}(G_p(a))$ to convert a numerical value a to another value close to a *preferred* value c.

Proof: Let $G_x(a) = a - x$where x is the parameter for G. Then $G_x^{-1}(a')$ =a+x . Also, let p=a-$\varepsilon$and q=c where $\varepsilon$is a small value. Then, the compound mapping $G_q^{-1}(G_p(a))$ of a yields b as

b=$G_q^{-1}(G_p(a))$=G_q^{-1}(a-p)=$G_q^{-1}(\varepsilon)$

$= \varepsilon + q = \varepsilon + c$

Which means that the value b is close to the preferred value c. The above lemma relies on two assumptions. The first is that p is close to a, or equivalently, that p=a- ε. The reasonwhy we derive the above lemma for p=a- ε. Instead of for p=a, is that in the reverse mapping we want to recover a from$b$ without knowing a, which is a requirement in the applications of reversible visible watermarking investigated in this study. Although the value of cannot be known in advance for such applications, it can usually be estimated, and we will describe some techniques for such estimations in the subsequent sections.

The second assumption is that $G_x(a)$yields a small value if x and a are close. Though the basic difference function $G_x(a) = a - x$ used in the above proof satisfies this requirement for most cases, there is a possible problem where the mapped value may exceed the range of valid pixel values for some values of p,$q$and a. For example, when p=255,q=255 and a=253, we have b=255-253+255=257>255. It is possible to use the standard modulo technique (i.e., taking $b=257_{mod\ 256} = 1$) to solve this issue; however, such a technique will make b 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,$G_x(a) = (a - x)_{mod\ 256}$, can still yield reasonable experimental results. Furthermore, we show in Section 5 a more sophisticated one-to-one function that is free from such a wraparound problem.

By satisfying the above two requirements, the compound mapping yields a value b that is close to the desired value c. We now prove a theorem about the desired lossless reversible visible watermarking in the following.

Theorem 1 (Lossless Reversible Visible Watermarking):
There exist one-to-one compound mappings for use to embed into a given image I a visible watermark Q whose pixel values are close to those of a given watermark L, such that the original image can be recovered from losslessly.
Proof:This is a consequence of Baby 1 and 2 after regarding the individual pixel values in I,L and Q respectively as those of p,l and q mentioned in Baby 2. And it is clear by Lemma 1 that the value can be recovered losslessly from the mapped value $q$which is derived in Baby 2.
The above discussions are valid for embedding a watermark in a grayscale image. If color images are used both as the cover image and the watermark, we can apply the mappings to each of the color channels to get multiple independent results. The resulting visible watermark is the composite result of the color channels.
Based on Theorem 1, the proposed generic lossless reversible visible watermarking scheme with a given image I and a watermark L as input is described as an algorithm as follows.

Algorithm 1: Visible Watermark Embedding
Input**:** an image I and a watermark L.
Output**:** watermarked image W.
Steps**:**
1) Select a set P of 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$W$ by .
3) For each pixel X with value $a$in , denote the corresponding pixel in Q as Z and the value of the corresponding *pixel* Y in L as c, and conduct the following steps.
a) Apply an estimation technique to derive to be a value close to , using the values of the neighboring pixels of X (excluding X itself).
b) Set to be the value c.
c) Map to a new value $b=G_q^{-1}(G_p(a))$.
d) Set the value of Z to be b.
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 .

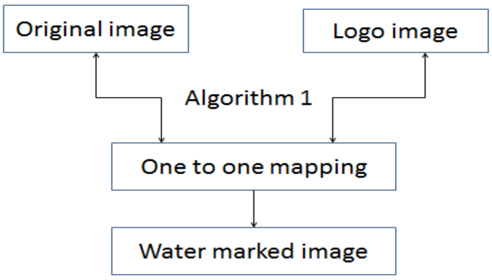


Figure.1 Visible Watermark Embedding

The proposed approach is shown in figure 1.The lossless reversible visible watermarking based on appropriate one to one compound mappings can be designed for embedding lossless different types of visible watermarks into images. The original image can be recovered loss from a resulting watermarked image by using the corresponding reverse mappings.

Algorithm 2: Watermark Removal for Lossless Image Recovery
Input**:** a watermarked image W and a watermark L.
Output**:** the original image R recovered from W.
Steps:
1) Select the same watermarking Q area in W as that selected in Algorithm 1.
2) Set the value of each pixel in , which is outside the region , to be equal to that of the corresponding pixel in W.
3) For each pixel Z with value $q$in Q, denote the corresponding pixel in the recovered image R as X and the value of the corresponding pixel Y in L as c, and conduct the following steps.
a) Obtain the same value p as that derived in Step 3a of Algorithm 1 by applying the same estimation technique used there.
b) Set q to be the value c.
c) Restore a from b by setting $a=G_p^{-1}(G_q(b))$.
d) Set the value of X to be a.

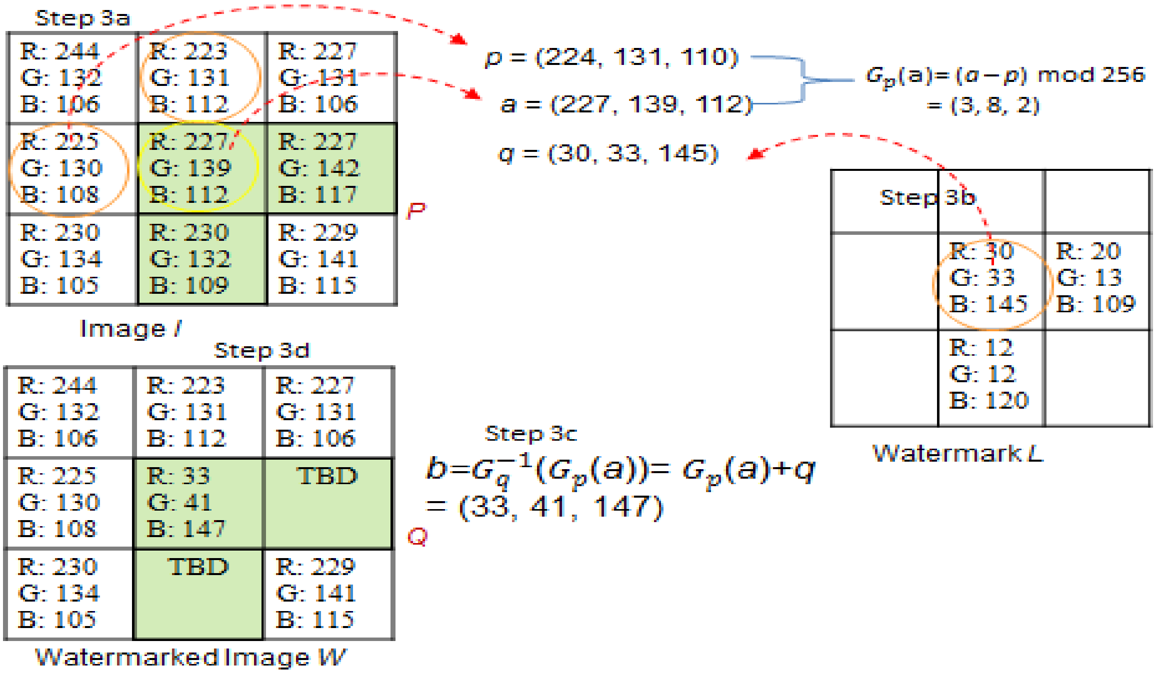


Fig. 2. Illustration of mapping the center pixel of a 3x3 image using Algorithm 1. Only the mapping of the center pixel is shown for clarity; the east and south pixels are depicted as TBD (to be determined) in *W*.

(a) (b) (c)

Figure3.Illustration of pixels in a watermark. (a) A monochrome watermark (logo image). (b) Original image. (c) Watermarked image

2.1 Lossless Visible Watermarking Of Opaque Monochrome Watermarks For Embedding:

First, we denote the sets of those pixels in Icorresponding spatially to the *black* and *white* pixels in L by P and P', respectively. An illustration of such areas of P and P' is shown in Fig. 2. We define Q and Q'in a similar way for the watermarked image *W*, which correspond to *P* and P' , respectively.

Then, we adopt the simple one-to-one function $G_p(a)$ =*a-p*, and use the same pair of parameters and for *all* mappings of pixels in P. Also, we apply the “modulo-256” operation to the results of all computations so that they are within the valid range of color values. Our experiments show that this method still yields reasonable results.

As to the values of parameters *p* and *q*, we set p to be the *average* of the color component values of the pixels in P'. This average value presumably is close to the value *a* of pixel *X* in *P*, fulfilling the condition $p=a-\varepsilon$ mentioned previously. To ensure that the watermark is distinctive in *W*, we do not simply embed black values for pixels in watermarking area *P* (that is, we do not embed *c=0* for *P*), but set *c* to be a value which is distinctive with respect to the pixel colors in the surrounding region P'. To achieve this, we set *q=c=p+128*, which is a value *distinctive* with respect to *p* . As a result, the value of a pixel in *Q*, according to Baby2, becomes $b=G_q^{-1}(G_p(a))= q+ \varepsilon=p+128+ \varepsilon$, meaning that the pixel values *Q* of are also distinctive with respect to those of the surrounding pixels in Q'.

2.2 Reverse One To One Compound Mapping For Watermark Removing:

Identical parameter values can be calculated by the receiver of a watermarked image for the purpose of lossless image recovery. As an example, the process performed by Step 3 of the above algorithm for a pixel is illustrated by Fig. 3, where the north and west pixels are used to estimate the color of the center pixel. Note that the east and south pixels are not used because these pixels are covered by the watermark and unknown to the receiver. It is important to allow as many neighbors of a pixel as possible to be known by the receiver to ensure that a good estimate can be calculated for that pixel. We will describe in Section 4 techniques for processing pixels, which can ensure that sufficiently many neighbor colors are known by a receiver for each pixel in the watermarking area. The corresponding watermark removal process for a watermarked *W* image generated by Algorithm 1 is described as an algorithm as follows.

2.3 lossless Visible Watermarking Of Translucent Color Watermarks

As another application of the proposed approach, we describe now how we embed more complicated translucent color watermarks. A translucent color watermark used in this study is an arbitrary RGB image with each pixel being associated with an alpha component value defining its opacity. The extreme alpha values of 0 and 255 mean that the watermark pixel is completely transparent and totally opaque, respectively. A translucent full-color watermark is visually more attractive and distinctive in a watermarked image than a traditional transparent monochrome watermark, as mentioned previously. Such a kind of watermark can better represent trademarks, emblems, logos, etc., and thus is more suitable for the purpose of advertising or copyright declaration.

The proposed algorithm for embedding a translucent color watermark is similar to Algorithm 1 and is described below. To ensure that the parameter p is close to a for each pixel, we keep track of the pixels that have been processed throughout the embedding process. The pixels outside region P need not be processed and are regarded as having been processed

Algorithm 3: Watermark Embedding of a Translucent Color Watermark

Input: an image I and a translucent watermark L.

Output: a watermarked image W.

Steps:

1) Select the watermarking area P in I to be the set of pixels corresponding spatially to those in L which are nontransparent (with alpha values larger than zero).

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

3) For each pixel X with value a in P, denote the corresponding pixel in Q as Z and the value of thecorresponding pixel Y in L as c, and conduct the following steps.

a) Set the parameter to be a neighbor-based color estimate value that is close to a by using the colors of the neighboring pixels of X that have alreadybeen processed (see discussion below).

b) Perform alpha blending with c over p to get the parameter q according to the formula $q=c \times \alpha + p \times (255-\alpha)$ where α is the opacity of Y.

c) Map to a new value $b=G_q^{-1}(G_p(a))$..

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.

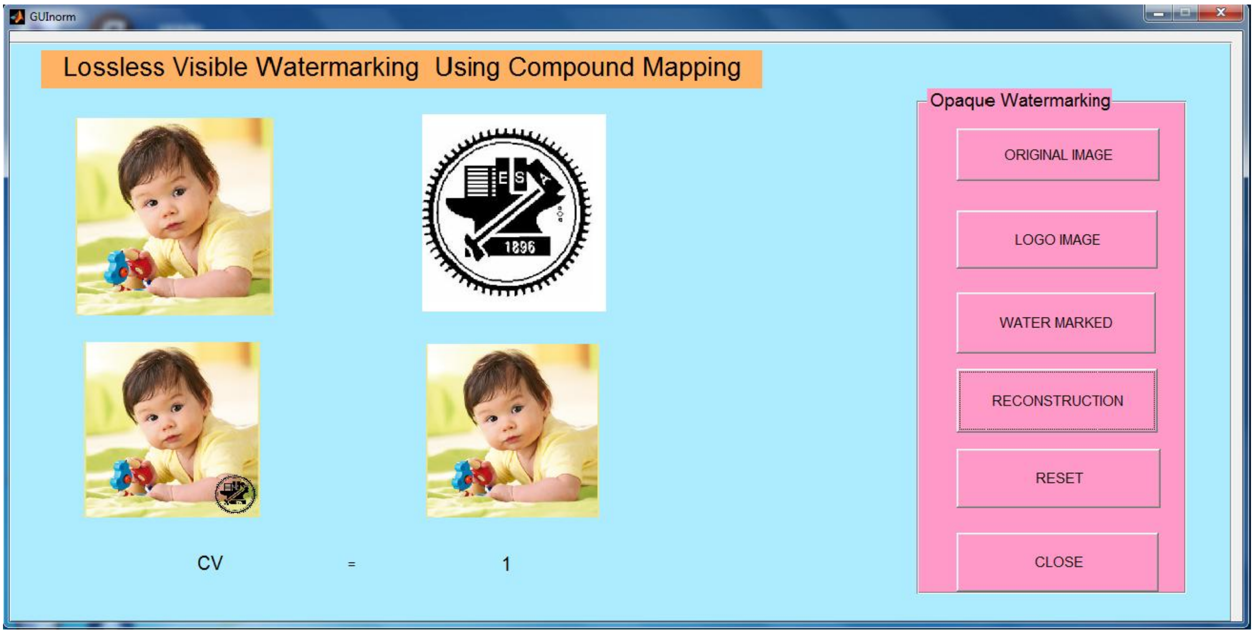
For Step 3a above, there are several ways to determine the color estimate of a pixel using the colors of its neighbors that have already been processed, such as simply averaging the colors of the processed 4-neighbors of the pixel, or averaging those of the processed 8-neighbors with more weights on the horizontal and vertical members.We may also use more sophisticated techniques such as edge-directed prediction [21] for this purpose, as long as we use only processed pixels.

The reason for using only processed pixels is that these pixels are the ones that a receiver can reliably recover during watermark removal. This is to ensure that the same color estimates can be computed for lossless recovery. Specifically, the value q of the first processed pixel is computed from the neighboring pixels outside the region P. Since the values of these pixels outside P are unchanged, a receiver can, therefore, reliably recover the first pixel using a reverse mapping using q and the values of neighboring pixels outside P. Each of the other unprocessed pixels is handled by using the processed pixels in a similar way

Fig. 4. Watermarked image of scenary with a translucent image of “Globe” superimposed using alpha blending.

2.4 extracting Translucent Color Watermarks:

In this paper can overlay the translucent watermark over the original image with an application package like Photoshop using the standard alpha blending operation to obtain a watermarked image, as illustrated in figure 5 Such an image will be called a non-recoverable watermarked image in the sequel, and will be used as a benchmark in our experiments



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CV = 1

Figure5: Opaque Watermarking

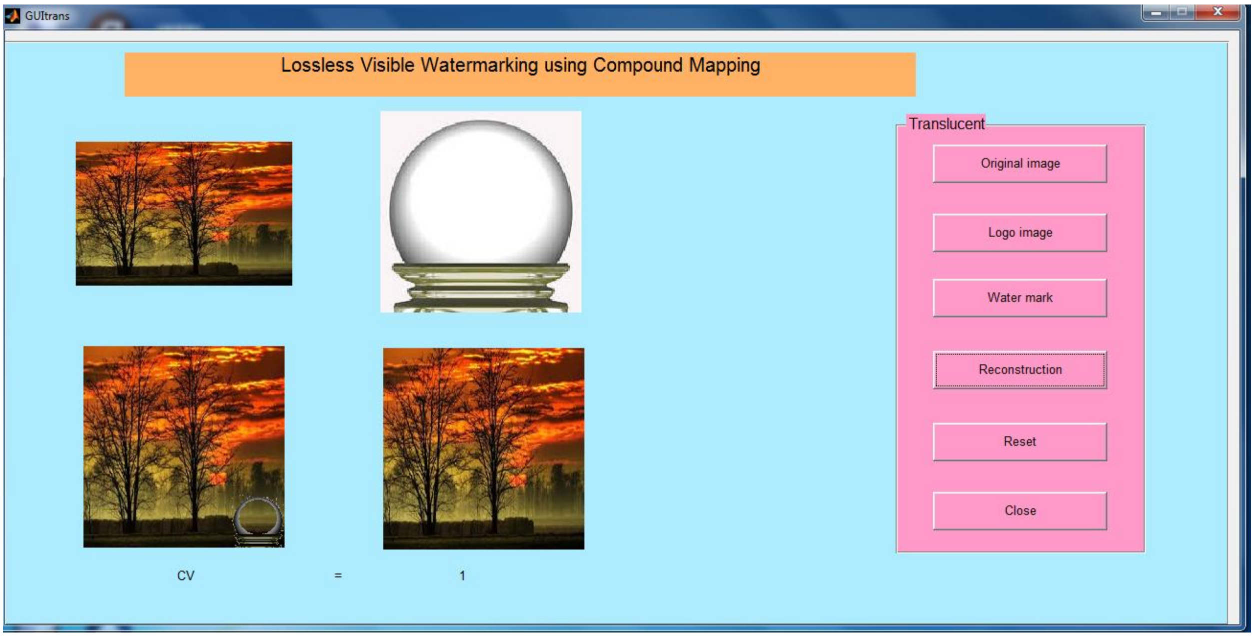

Figure6: Translucent watermarking

III. EXPERIMENTAL RESULTS:

A series of experiments implementing the proposed methods were conducted using the Java SE platform.1 To quantitatively measure the effectiveness of the proposed method, we define a set of performance metrics here. First, the quality of a watermarked image W is measured by the peak signal-to-noise ratio (PSNR) of W with respect to the nonrecoverable watermarked image B in the following way:

$$\mathrm{PSNR_W}{=}20\times \log_{10}(255/\sqrt{\frac{1}{w\times h}\sum_{y=1}^{h}\sum_{x=1}^{w}[W(x,y)-B(x,y)]^2}\ ).$$

Also, the quality of a recovered image R is measured by the PSNR R of with respect to the original image I in a similar way

$$\mathrm{PSNR_R}{=}20\times \log_{10}(255/\sqrt{\frac{1}{w\times h}\sum_{y=1}^{h}\sum_{x=1}^{w}[R(x,y)-I(x,y)]^2}\ ).$$

It is desired to have the value of the $\mathrm{PSNR}_W$to be as high as possible, so that the watermarked image can be visually as close to the benchmark image as possible. For illicit recoveries, the PSNR_R should be as low as possible to make the recovered image visually intolerable (e.g., very noisy). In particular, we want the region obscured by the watermark to be as noisy as possible in an illicitly recovered image. For this purpose, we introduce an additional quality metric for an illicitly recovered image that only takes into account the region Q covered by the watermark. Specifically, we measure the quality of the recovered image R by the following PSNR measure:

$$\mathrm{PSNR_Q}{=}20\times \log_{10}(255/\sqrt{\frac{1}{|\mathrm{Q}|}\sum_{y=1}^{h}\sum_{x=1}^{w}\mathrm{SE_Q}(x,y)}\ ).$$

Where

$$SE_Q(x{,}y){=}\begin{cases}[\mathrm{R}(x,y)-I(x,y)]^2, \mathrm{if}(x,y)\in Q\\ 0 \qquad\qquad\qquad\quad \mathrm{if}(x,y)\notin Q.\end{cases}$$

One test image, of dimension 512 512, were used in the experiment. They are shown in Fig. 6, referred to as “Baby” respectively. And five test watermarks were used in the experiments as shown in Fig. 7, here in after referred to as watermarks A, B, C, D and E, respectively. The width and height of each watermark are135 135, along with the number of nontransparent pixels in each watermark and several other properties described next. The *average opacity*, as shown in the

A B C D E

Figure7: A through E used in experiments

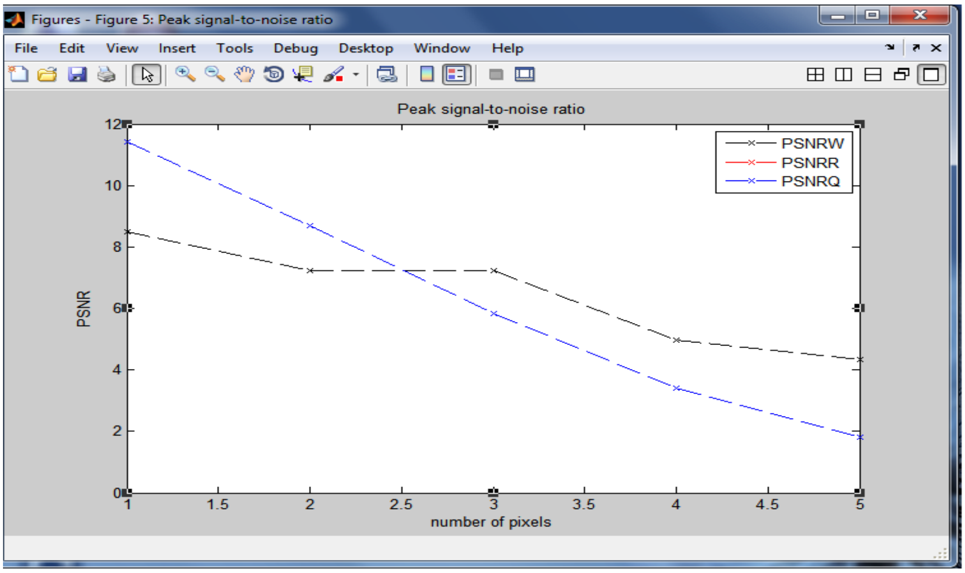

Figure8: Average values of PSNR$_W$ obtained after watermark embedding and average values of PSNR$_R$ and PSNR$_Q$ obtained after illicit image recoveries.

IV. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

In this paper, a new method for reversible visible watermarking with lossless image recovery capability has been proposed. The method uses one-to-one compound mappings that can map image pixel values to those of the desired visible watermarks. Relevant lemmas and theorems are described and proved to demonstrate the reversibility of the compound mappings for lossless reversible visible watermarking. The compound mappings allow different types of visible watermarks to be embedded, and two applications have been described for embedding opaque monochrome watermarks as well as translucent full-color ones. A translucent watermark is clearly visible and visually appealing, thus more appropriate than traditional transparent binary watermarks in terms of advertising effect and copyright declaration. The two-fold monotonically increasing property of compound mappings was defined and an implementation proposed that can provably allow mapped values to always be close to the desired watermark if color estimates are accurate. Also described are parameter randomization and mapping randomization techniques, which can prevent illicit recoveries of original images without correct input keys. Experimental results have demonstrated the feasibility of the proposed method and the effectiveness of the proposed security protection measures. Future research may be guided to more applications of the proposed method and extensions of the method to other data types to Embed the logos in .AVI videos this project can be further enhanced based on the future trends and strategies.

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