



Video Watermarking of Which Embedded Information Depends on the Distance between Two Signal Positions

Kuribayashi, Minoru

Tanaka, Hatsukazu

(Citation)

IEICE transactions on fundamentals of electronics, communications and computer sciences, E86-A(12):3267-3275

(Issue Date)

2003-12-01

(Resource Type)

journal article

(Version)

Version of Record

(Rights)

Copyright (c) 2003 IEICE

(URL)

<https://hdl.handle.net/20.500.14094/90001349>



PAPER

Video Watermarking of Which Embedded Information Depends on the Distance between Two Signal Positions

Minoru KURIBAYASHI^{†a)}, *Regular Member* and Hatsukazu TANAKA[†], *Fellow*

SUMMARY One of the important topics of watermarking technique is a robustness against geometrical transformations. In the previous schemes, a template matching is performed or an additional signal is embedded for the recovery of a synchronization loss. However, the former requires the original template, and the latter degrades the quality of image because both a watermark and a synchronization signal must be embedded. In the proposed scheme only a synchronization signal is embedded for the recovery of both a watermark and a synchronization loss. Then the embedded information depends on the distance between two embedded signal positions. The distance is not changed seriously by random geometrical transformations like StirMark attack unless the embedded signal is disturbed. Therefore, a watermark can be extracted correctly from such geometrically transformed image if the synchronization signal can be recovered.

key words: watermark, synchronization signal, StirMark, patchwork, video sequence

1. Introduction

According to the recent advances of information technology in the World Wide Web, digital contents are often treated via an internet for a commercial purpose. However, digital contents can be copied easily without any degradation and hence the copyright protection is the important problem in this field. Digital watermarking [1] is one of the effective schemes to protect the copyright of authors by preventing the illegal copy of digital contents. The digital watermark is an embedded signal to carry some author's proper information, which can not be perceived but can be extracted only by the authorized party. Therefore, the author can claim his copyright if the embedded signal indicates his proper information.

A watermark should retain the important feature so that it may not be deleted even if any kind of signal processing, such as linear or nonlinear filtering, non-invertible compression, addition of noise, etc. were performed. In general, many proposed schemes can immunize the above attacks, but the robustness against geometrical transformations such as rotation, scaling, translation, etc. is difficult to achieve because the coordinate of embedding position is different from that of extracting. Some schemes [2], [3] can immunize such

geometrical attacks so as to embed a watermark in the invariant domain against the attacks. However, if an image is bent slightly and randomly by several geometrical attacks, it is extremely difficult to extract a watermark in such schemes. We call such attack random geometrical attack. Therefore, it is necessary to recover the coordinate of the embedded position if random geometrical attack are performed. For still images we had already proposed a template matching method [4], [5] to recover the coordinate. It works effectively but requires whole or a part of the original image, and the amount of required memory becomes very large when it is applied for a video sequence. Kusanagi et al. [7] had proposed a new recovery scheme using a patchwork algorithm [8]. In their scheme a synchronization signal is inserted in several positions to tolerate for random geometrical attack. Then two kinds of signals, a watermark and a synchronization signals, must be embedded in the video sequence and hence the quality will be degraded. And to recover the synchronization loss, first they extract a synchronization signal and then correct the distortions caused by random geometrical attack. Therefore it needs additional heavy computation before extracting a watermark.

In this paper, we propose a new scheme to embed a watermark in the video sequence. When a synchronization signal is embedded, a watermark is embedded as a distance between two signal positions. Generally a position where a watermark has been embedded may be changed by random geometrical attack, but the distance between two signal positions will not be affected seriously. Therefore, a watermark can be extracted correctly even if such geometrical attack would be performed. And the watermark extraction and recovery of synchronization signal can be performed by easy computations as the correction of the distortions caused by random geometrical attack dose not need in our scheme. In order to embed a synchronization signal, a patchwork algorithm is applied because it is well known that a synchronization signal can remain in a video sequence even if random geometrical attack were performed [7]. However, the recovered positions are not always reliable as a wrong position may be selected, and hence the watermark may not be extracted correctly. In order to improve the reliability, a correction method is introduced and the performance is evaluated by computer simulation.

Manuscript received July 23, 2002.

Manuscript revised May 12, 2003.

Final manuscript received August 20, 2003.

[†]The authors are with the Faculty of Engineering, Kobe University, Kobe-shi, 657-8501 Japan.

a) E-mail: minoru@eedept.kobe-u.ac.jp

Embedding synchronization signals may be a best solution to achieve a robustness against random geometrical attack. Previously such signals are used only for the recovery of the synchronization loss. Our scheme shows the possibility of the another usage of the synchronization signals, which is a new channel to embed a watermark. Such a new channel will be very attractive to embed an information if the synchronization signal is used to tolerate for the robustness against random geometrical attack. Furthermore, if the amount of watermarking information is small, only our scheme is applied, otherwise hybrid system, both our scheme and conventional watermarking scheme, may be applied.

This paper is organized as follows. In Sect.2 an embedding algorithm and attacks what we apply in this paper are described. Section 3 describes a new method for embedding and extracting a watermark. The validity of our scheme is evaluated in Sect. 4. Finally we conclude this paper.

2. Preliminary

2.1 Patchwork Algorithm

The patchwork algorithm which is based on the statistical distribution is proposed in 1995 by Bender et al. [8]. In the embedding process, a pair of pixels of which luminance values are a_i and b_i is selected pseudo-randomly. Let s_i be given by

$$s_i = a_i - b_i, \quad (1)$$

then the average value of s_i is expected to be zero, and the summation of s_i

$$S(n) = \sum_{i=0}^{n-1} s_i = \sum_{i=0}^{n-1} (a_i - b_i) \quad (2)$$

has a Gaussian distribution if the number of samples is large enough. When 1-bit information is embedded, Eq. (2) is changed to the following $\hat{S}(n)$, where α is a positive integer.

$$\hat{S}(n) = \sum_{i=0}^{n-1} ((a_i + \alpha) - (b_i - \alpha)) \quad (3)$$

$$= \sum_{i=0}^{n-1} (a_i - b_i) + 2n\alpha \quad (4)$$

Then the distribution of $\hat{S}(n)$ shifts to the positive direction (see Fig. 1).

In patchwork algorithm the number of samples should be large. If the operation is performed only in a small block, the embedded signal may not be extracted correctly. In order to embed in a small block, the operation is performed for several frames of a movie file. So our proposed scheme uses the patchwork algorithm to embed a synchronization signal in a video sequence

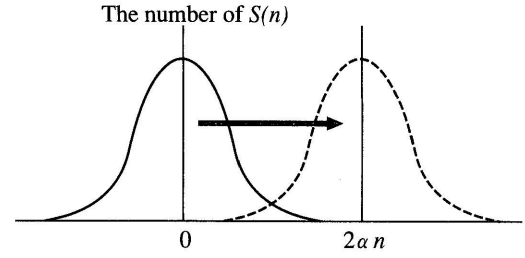


Fig. 1 The number of $S(n)$.

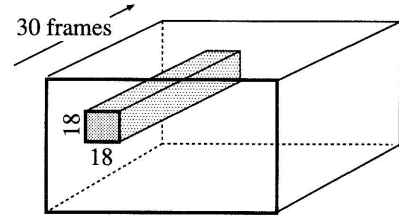


Fig. 2 A target area of the patchwork.

of 18×18 pixel block of 30 frames. If the block size becomes large, the computational cost increases though the number of necessary frame decrease and vice versa. Therefore considering the trade-off, we define the parameters as above. Figure 2 illustrates the embedding region in which each pair of pixels is selected randomly.

2.2 Geometrical Attack

StirMark attack[†] [9] is a widely used benchmark tool to evaluate a watermarking technique. It changes an image slightly by rotation, stretch, shift, shear, etc. when it is performed with default parameter. Since the StirMark attack performs such attacks randomly, the attacked image will be different in every time. The randomness gives no effect for the evaluation of a still image, but affects seriously if a different attack is performed to each frame because there is a strong correlation among several frames. Hence we perform the same attack to each frame by setting a seed parameter “-s,” where other parameters are defaults.

In an extraction algorithm, the shifted and rotated position should be recovered. We have proposed a searching protocol in [4] and [5] of which simulation results indicate that the amount of shift σ is $-6 \leq \sigma \leq 6$ in both horizontal and vertical directions. Therefore the position embedded a synchronization signal should be searched in such area. As a consequence, our scheme can recover the embedded watermark if slight rotation, shift, row and column removal attack, and even StirMark attack are performed.

[†]StirMark3.1 : <http://www.cl.cam.ac.uk/~fapp2/watermarking/stirmark31/index.html>

3. Proposed Scheme

In this section we propose a new idea on how to embed a watermark and how to extract it ingeniously. Taking the random geometrical attack into account, synchronization signals are embedded into some blocks of which positions can be determined uniquely by a watermark.

3.1 Embedding

In our scheme the distance between two embedded positions of synchronization signals depends on the watermark. $N_X \times N_Y$ synchronization signals are embedded in blocks $B_{x,y}$, ($0 \leq x < N_X, 0 \leq y < N_Y$) of 30 frames by the following patchwork algorithm, where the block size is 18×18 . Here the bit-length of a watermark is $N_w = 2N_X N_Y - N_X - N_Y$. Before embedding a watermark, the initial positions must be determined by a secret key in order to specify synchronization positions uniquely by a watermark.

Let $(X_{B_{x,y}}, Y_{B_{x,y}})$ be the coordinate of an upper left pixel in the block $B_{x,y}$ and be a position of synchronization signal. Then, using a secret key, the initialization process is performed.

Step 1. Specify the first initial position from the upper left region using a secret key, which coordinate is $(X_{B_{0,0}}, Y_{B_{0,0}})$, $6 \leq X_{B_{0,0}}, Y_{B_{0,0}} \leq 12$.

Step 2. Initial coordinates $Y_{B_{0,j}}$ and $X_{B_{i,0}}$ are determined by the following equation respectively.

$$Y_{B_{0,j}} = Y_{B_{0,0}} + 35j + \delta_{0,j}, \quad (1 \leq j < N_Y), \quad (5)$$

$$X_{B_{i,0}} = X_{B_{0,0}} + 35i + \delta_{i,0}, \quad (1 \leq i < N_X), \quad (6)$$

where $\delta_{0,j}$ and $\delta_{i,0}$ are random numbers satisfying the following inequalities.

$$|\delta_{0,j}| < 4, \quad |\delta_{i,0}| < 4 \quad (7)$$

In the initialization process each parameter is determined considering the following property. As the edge of a frame sometimes contains redundancy, it may be clipped by an attacker. Since the amount of shift caused by StirMark attack is $-6 \leq \sigma \leq 6$, the region which is in 6 pixels from the edge will be removed by the attack. So it is better to avoid embedding a watermark in such region and hence we determine the initial position $(X_{B_{0,0}}, Y_{B_{0,0}})$ in the above defined range. If the embedding position is selected from a few candidates, an attacker may be able to find easily. However if the number of candidates is increased, the number of embedding signal is decreased. Therefore considering the trade-off, we define each parameter in Eq. (5) and Eq. (6).

From each initial coordinate two lines can be drawn as shown in Fig. 3. Then a synchronization signal is embedded in the intersections. The position of a block

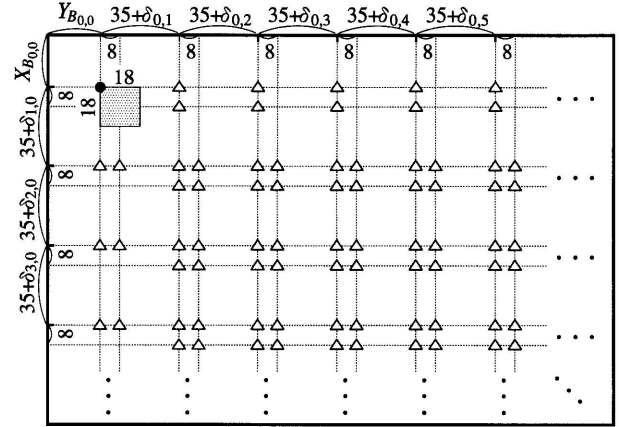


Fig. 3 The candidates of each embedding position determined by a watermark. Where Δ is the candidates of the embedding positions.

$B_{0,0}$ has already determined in the initialization process and the others can be taken from one of two or four possible positions indicated by a triangle in Fig. 3. The position is determined uniquely using the distance between two adjoining blocks which depends on a watermark. Here, the number of pairs of two adjoining blocks to the horizontal direction is $N_Y - 1$ in each column and hence the total number is $P_Y = N_X(N_Y - 1)$. Similarly, that of vertical direction is $P_X = N_Y(N_X - 1)$. Therefore we can decide $P_X + P_Y$ distances for synchronization signals to be embedded and hence the bit-length of the watermark is $N_w = P_X + P_Y = 2N_X N_Y - N_X - N_Y$. Let $w = \{w_t \mid w_t \in \{0, 1\}, (0 \leq t < N_w)\}$ be a watermark information vector. Then, each position for a synchronization signal to be embedded is determined by a watermark as follows, where the coordinate of X and Y are the vertical and horizontal direction respectively.

Horizontal Direction ($t = 0$)

```

for  $x = 1$  to  $N_X$  do
{
  for  $y = 0$  to  $N_Y$  do
  {
    if  $w_t = 0$  then
       $Y_{B_{x,y}} = Y_{B_{x-1,y}}$  (8)
    else
      {
        if  $Y_{B_{x-1,y}} \pmod{35} < Y_{B_{0,0}} + 4$  then
           $Y_{B_{x,y}} = Y_{B_{x-1,y}} + 8$  (9)
        else
           $Y_{B_{x,y}} = Y_{B_{x-1,y}} - 8$  (10)
        }
      }
     $t = t + 1$ 
  }
}

```

Vertical Direction ($t = P_Y$)

for $y = 1$ to N_Y do

{
 for $x = 0$ to N_X do
 {
 if $w_t = 0$ then

$$X_{B_{x,y}} = X_{B_{x,y-1}} \quad (11)$$

else
 {

 if $X_{B_{x,y-1}} \pmod{35} < X_{B_{0,0}} + 4$ then

$$X_{B_{x,y}} = X_{B_{x,y-1}} + 8 \quad (12)$$

 else

$$X_{B_{x,y}} = X_{B_{x,y-1}} - 8 \quad (13)$$

 }
 $t = t + 1$

}}

After determining the embedding position, a synchronization signal is embedded using a patchwork algorithm. Here, the conventional algorithm should be modified adaptively considering the distortions because a signal embedded in the smooth area of an image becomes more perceptible compared with the noisy area. Therefore, at a pixel a_i the value α in Eq. (3) is replaced with

$$\alpha_{a_i} = \beta(1 + \gamma \cdot T_{a_i}), \quad (14)$$

where β and γ are constant positive weighting parameters, and T_{a_i} is a parameter which depends on the variations in the pixel. From Eqs. (4) and (14) it is guaranteed that the distribution of $S(n)$ is shifted to at least $2\beta n$ from zero and the distribution is illustrated in Fig. 4, where h is a threshold to determine the position whether a patchwork signal is embedded or not. Generally, the Laplacian operator is used for the detection of the edge area, but the operator is sensitive to noise. Then the Sobel operator [10] is used to determine the weight in our scheme as it gives better results. Let $f(a_i)$ be an output value of the Sobel operator at a pixel a_i and str be an embedding intensity. Then T_{a_i}

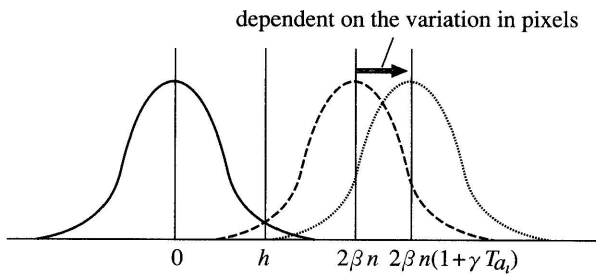


Fig. 4 Changes in a distribution of $S(n)$.

is given by the following equation.

$$T_{a_i} = \begin{cases} f(a_i) & \text{if } f(a_i) < str \\ str & \text{otherwise} \end{cases} \quad (15)$$

3.2 Extraction

The watermark can be extracted according to the distance between two synchronization positions. So the synchronization positions should be detected first. Then only the possible two or four positions illustrated by the triangles in Fig. 3 should be checked after determining the same initial position as determined in the embedding process. However, if random geometrical attack were performed, the positions should be searched in the area K depicted in Fig. 5. Therefore, the extraction process has the following hierarchical structure in our scheme. First, the possible two or four positions are examined for all $N_X N_Y$ intersections. If the sum of $S_{B_{x,y}}(n)$ is less than a threshold $N_X N_Y h$, each position in which $S_{B_{x,y}}(n)$ has the maximum value is selected from each area K .

The procedure to extract the watermark is shown as follows.

- Step 1.** Determine the same initial coordinates as determined in the embedding process.
- Step 2.** Perform the patchwork extraction process in the possible two or four positions shown by the triangles in Fig. 3. Then, the position where $S_{B_{x,y}}(n)$ has the maximum value is determined as the synchronization position.
- Step 3.** If the sum of $S_{B_{x,y}}(n)$ exceeds a threshold $N_X N_Y h$, then go to Step 5, else to the Step 4.
- Step 4.** Calculate $S_{B_{x,y}}(n)$ at every possible position in the search area K , and determine the position where $S_{B_{x,y}}(n)$ becomes maximum.
- Step 5.** In the horizontal and vertical directions the embedded watermark can be extracted as follows.

Horizontal Direction ($t = 0$)

for $x = 1$ to N_X do

{
 for $y = 0$ to N_Y do

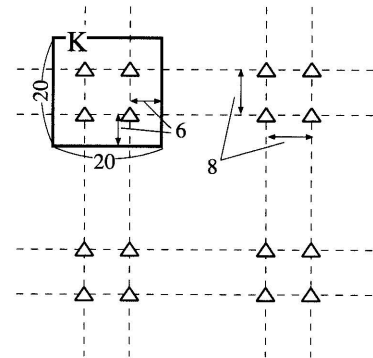


Fig. 5 The searching area K for each embedded position.

$$\{$$

$$D_y = |Y_{B_{x,y}} - Y_{B_{x-1,y}}| \quad (16)$$

$$\hat{w}_t = \begin{cases} 0 & D_y < 4 \\ 1 & 4 < D_y < 12 \\ NULL & \text{otherwise} \end{cases} \quad (17)$$

$t = t + 1$
 $\}}}$

Vertical Direction ($t = P_Y$)

for $y = 1$ **to** N_Y **do**
 $\{$
for $x = 0$ **to** N_X **do**
 $\{$

$$D_x = |X_{B_{x,y}} - X_{B_{x,y-1}}| \quad (18)$$

$$\hat{w}_t = \begin{cases} 0 & D_x < 4 \\ 1 & 4 < D_x < 12 \\ NULL & \text{otherwise} \end{cases} \quad (19)$$

$t = t + 1$
 $\}}}$

where *NULL* means that no watermark exists.

3.3 Correction Method

In the extraction process there is no grantee that the determined synchronization position is correct. If a wrong position is detected, then “*NULL*” may be returned as an error from the Eqs. (17) and (19). Then no operation is performed to the error position in the previous process. And if the distance D_y or D_x is accidentally in the range of which a watermark w_t can be judged zero or one, the wrong position seems to be impossible to correct. However, if almost all positions are detected correctly, the error may be able to correct from the following reason. The embedding positions should be on the intersections of horizontal and vertical lines illustrated in Fig. 3. Then a position far from the intersection can be estimated as a wrong position. Therefore the synchronization position can be recovered if the search is performed again around the intersection.

For the correction procedure, the following three steps should be inserted between Step 4 and Step 5 in the above extraction process.

1. Estimate the vertical lines $vline1[j]$ and $vline2[j]$ from $Y_{B_{i,j}}$, and the horizontal lines $hline1[i]$ and $hline2[i]$ from $X_{B_{i,j}}$ respectively.
2. Determine the possible area at each intersection as depicted in Fig. 6.
3. On the positions far from the area, search the position in which $S_{B_{x,y}}(n)$ takes the maximum value in the area.

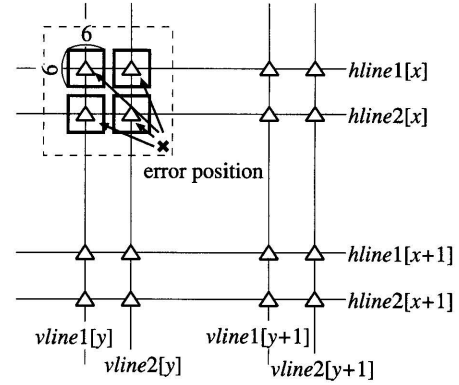


Fig. 6 The reduced searching area using estimated lines.

In Step 5 of the extraction process the detector may output *NULL* even if the position is in a correct area. For example, if $X_{B_{x,y}} = hline1[x] - 2$ and $X_{B_{x,y-1}} = hline1[x] + 2$, then $D_x = 4$. To improve the wrong detection of a watermark, Step 5 is modified to the following. In the horizontal direction we draw each line $vline[j]$ in the middle of $vline1[j]$ and $vline2[j]$. If both $Y_{B_{i,j}}$ and $Y_{B_{i-1,j}}$ are less than $vline[j]$ or more than $vline[j]$, then a watermark w_t is considered zero, else one. Similarly, the detection process in the vertical direction is also modified.

4. Computer Simulated Result

In order to evaluate our proposed scheme, computer simulation has been executed under the assumption that the MPEG-compression algorithm is applied for a video sequence, which is corrupted by the StirMark attack with default parameters. The detail specifications for computer simulation are given as follows. Test video sequences are “Flower Garden (F)” and “Tennis (T)” with 150 frames of 352×240 pixel, and only 30 frames are used to embed a synchronization signal. The length of the watermark information is 93 bits where $N_X = 6$ and $N_Y = 9$, and the number of patchwork is $54 (= 9 \times 6)$. Parameters in patchwork algorithm are $\beta = 1$, $\gamma = 0.1$ and the number of samples are set to 10,000. The numerical results given below are the average values of 1000 results.

4.1 Degradation

In order to evaluate the quality of the watermarked video sequence, PSNR is calculated in each frame which is embedded a synchronization signal. Since 30 frames are used to embed the signal, the average PSNR value of such frames are examined. Figure 7 depicted the result for embedding intensity *str*. Here, from the point of degradation the embedding intensity *str* can be set 50 for “Flower Garden” and 30 for “Tennis.”

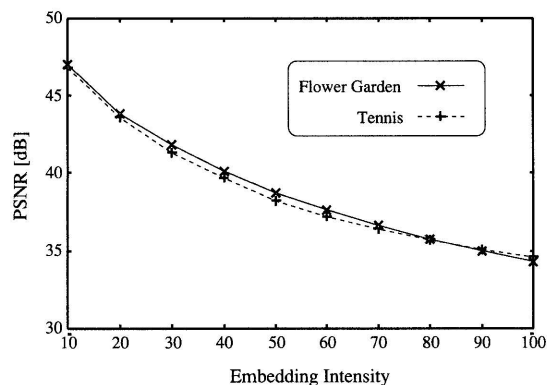


Fig. 7 PSNR versus embedding intensity.

Table 1 Tolerance for MPEG compression.

<i>str</i>	bit-rate [Mbps]	bit error rate	
		F	T
20	2	6.56	0.33
	3	1.95	0.00
	4	0.50	0.00
30	2	2.86	0.00
	3	0.49	0.00
	4	0.00	0.00
40	2	1.29	0.00
	3	0.97	0.00
	4	0.00	0.00
50	2	0.96	0.00
	3	0.89	0.00
	4	0.00	0.00

4.2 Non-geometrical Attacks

In this subsection we examine the robustness of our scheme against non-geometrical attacks such as MPEG compression, Gaussian filter and Median filter. Since the synchronization positions are not changed in such attack, the position is examined only from the possible two or four positions depicted in Fig. 3. First, a watermarked video sequence is compressed by the MPEG algorithm with low bit-rate to examine the robustness. Table 1 shows the average number of error bits in the watermark extracted from the compressed sequence with each bit-rate and the robustness against MPEG compression is different for each the video sequence. Here, if the embedded information is encoded by error correction code, the information can be derived correctly from the compressed image by error correction. Next, the robustness against Gaussian filter and Median filter are shown in Table 2 and Table 3, where the attacks are performed using the StirMark tool. For the embedding intensity $str = 50$ to “Flower Garden” and 30 to “Tennis,” the error rate is enough low, hence error correction code can work well. As the consequence, our proposed scheme retains a tolerance for non-geometrical attacks.

Table 2 Tolerance for Gaussian filter.

<i>str</i>	bit error rate	
	F	T
20	6.39	2.12
30	3.31	0.52
40	0.00	0.52
50	0.00	0.00

Table 3 Tolerance for Median filter.

<i>str</i>	bit error rate	
	F	T
20	14.81	2.67
30	5.41	1.02
40	2.18	1.02
50	0.97	1.02

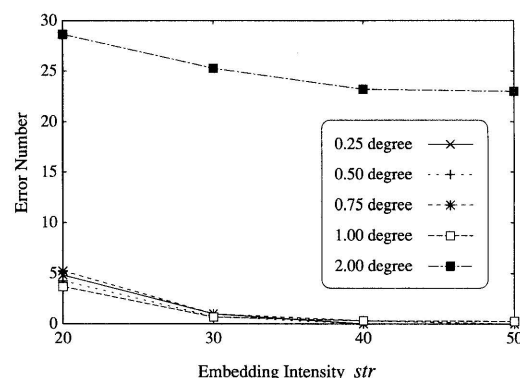


Fig. 8 Tolerance for rotation (Flower Garden).

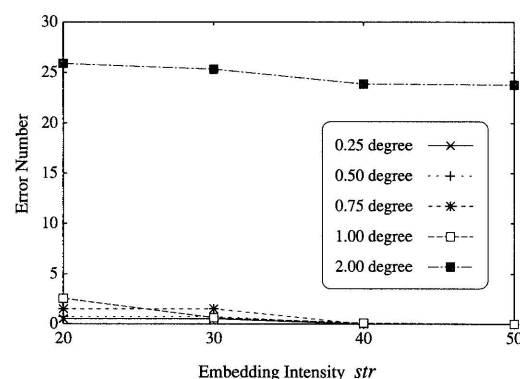


Fig. 9 Tolerance for rotation (Tennis).

4.3 Geometrical Attack

In this subsection, we perform several geometrical attacks included in StirMark to check the robustness. A watermarked video sequence is rotated slightly so as not to spoil the quality of the image. The extraction results after the rotation are shown in Fig. 8 and Fig. 9. From those figures if the angle is less than 2 degree, such rotation dose not affect seriously to extract a watermark.

Next row and column removal attack is performed

Table 4 Tolerance for five columns and rows removal attack.

<i>str</i>	bit error rate			
	F		T	
20	3.52	(4.16)	0.45	(0.62)
30	1.38	(1.74)	0.15	(0.28)
40	0.62	(0.79)	0.07	(0.15)
50	0.26	(0.30)	0.05	(0.09)

Table 5 Tolerance for random geometrical attack.

<i>str</i>	bit error rate			
	F		T	
20	6.83	(8.36)	1.35	(2.12)
30	2.10	(3.04)	0.61	(1.01)
40	0.89	(1.59)	0.33	(0.60)
50	0.59	(1.24)	0.37	(0.17)

Table 6 Tolerance for StirMark attack.

<i>str</i>	bit error rate			
	F		T	
20	15.03	(16.93)	4.70	(5.92)
30	5.80	(7.23)	2.73	(3.72)
40	2.81	(3.72)	1.89	(2.66)
50	1.93	(2.59)	1.40	(2.04)

to evaluate the robustness. Since the quality of the image is degraded with respect to the number of removed raw and column, only five rows and columns selected randomly are removed in our simulation, which results are shown in Table 4. From the results, our scheme can immunize the row and column removal attack.

Random geometrical attack is performed to evaluate the robustness of our scheme. Then a same attack is used to every frame in a watermarked video sequence. Table 5 shows the results, where the value in the parenthesis indicates the average bit error rate obtained without correction method. It is evident that the correction method can improve the decision error on synchronization positions. And the results indicate that our scheme can immunize the random geometrical attack.

Table 6 shows the tolerance for the StirMark attack with default parameters. Then every frame is attacked using a same seed parameter “-s,” where the version of StirMark is 3.1. Table 6 shows the results. From the results, StirMark attack which performs several attacks dose not affect seriously to the embedded signal. If $str = 50$ for “Flower Garden” and 30 for “Tennis,” then the error rate is not so high that a watermark may be extracted well with the aid of error correction.

4.4 Consideration

If the embedding intensity is increased, the robustness can be improved, but the degradation of the image becomes large, which is a trade-off. In our scheme the embedding intensity is set different for two video sequences according to their characteristics. Because the degra-

dation in the region that has a motion becomes less perceptible than in the motionless region, which is similar to the relation between noisy area and smooth area. For “Flower Garden” the whole region in the frame moves and contains a lot of high frequency components. On the other hand, the background of “Tennis” dose not move for several frames though it is noisy pattern. Therefore, the embedding intensity can be raised for the case of “Flower Garden.” From the above fact, the embedding intensity str should be changed dependent on not only the character of one frame but also the motion among several frames. Further a weight parameter T_{a_j} should be determined considering the motion, which is left for our future work.

Our proposed scheme applies patchwork algorithm to embed a synchronization signal in a video sequence. Since the main idea is to embed a watermark as an information about distance between two synchronization signal positions, if there is better method to embed a synchronization signal, our scheme can be modified by exploiting it.

5. Comparison with Other Schemes

Watermarking schemes robust against random geometrical attack can be classified into the following five methods.

- Use an original image for the recovery of the synchronization.
- Embed in the low frequency components.
- Use the feature points.
- Embed both a watermark and a synchronization signal.
- Embed a periodical watermark.

Several schemes [4], [5], [12] apply the original work to recover the synchronization loss and show the good results, but it is not desirable to use the original work in extraction operation.

A watermark embedded in the low frequency components is not seriously affected by the attack. In [11] a watermark is embedded in the very low DCT coefficients of chrominance components, but the scheme needs a lot of computation to transform the whole image to the frequency domain and reduces the security of the secrecy of the embedding position as there are only a few candidates for the positions which should be selected from the very low frequency components. But the patchwork algorithm in our scheme can use a secret key from a lot of candidates, and the parameters of $\delta(0, j)$ and $\delta(i, 0)$ are also the secret.

In [13] the feature points are used to divide an image into regions which shape are triangle, and a watermark is embedded in such regions via an affine transformation. The triangle is affected by random geometrical attack, but the distorted triangle can be specified using the feature points and hence the synchronization

can be recovered. If the scheme is applied for a movie file, every frame should be independently performed the resynchronization process. The scheme seems to be able to extract a watermark from a geometrically distorted image more accurately than our scheme as the distortion can be recovered adaptively for each frame, but the computational complexity may be larger than us. There is a trade-off between the computational complexity and the accurate extraction, it may depend on the situation for the applied system.

Our method recovers the synchronization loss using a synchronization signal. And the synchronization signal is ingeniously utilized to embed a watermark though it is embedded only for the recovery of the loss in the conventional scheme [7]. If the amount of embedded information in our scheme dose not satisfy the needs for an applied system, an ordinal watermarking method should be used to embed more information. Then the synchronization loss can be recovered by the signal embedded using our method. For example, 18 patchwork is embedded in [7] as a synchronization signal. If our scheme is applied, extra 27 bits information may be embedded as a watermark, where $N_X = 3$, $N_Y = 6$, $N_w = 2N_X N_Y - N_X - N_Y = 27$.

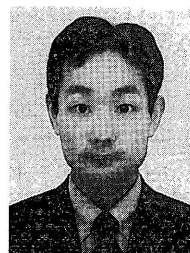
Embedding a periodical watermark proposed in [14] is one of a remarkable methods to recover a synchronization loss. The periodical pattern gives an information about the synchronization to the detector. However, it may also give the information to an attacker, though the detection rate will be higher than that of our scheme.

6. Conclusion

We have proposed a new idea to embed a watermark in a video sequence. It is embedded as the distance between two signal positions embedded for synchronization. Our proposed method has the following two advantages. First, the degradation of image can be improved because only the synchronization signal is embedded for the recovery of both a watermark and a synchronization loss. Second, a robustness against random geometrical attack can be achieved as the distance is not changed seriously by the attack. Though sometimes wrong positions are detected in the recovery process, an error correction method can be applied for correcting the detection error. As the consequence, our scheme immunizes the StirMark attack, which can be certified by our simulated results.

References

- [1] S. Katzenbeisser and F.A.P. Petitcolas, *Information hiding techniques for steganography and digital watermarking*, Artech House, 2000.
- [2] J.J.K. O'Ruanidh and T. Pun, "Rotation, scale and translation invariant spread spectrum digital image watermarking," *Signal Process.*, vol.66, no.3, pp.303-317, 1998.
- [3] C.Y. Lin, M. Wu, J.A. Bloom, I.J. Cox, M.L. Miller, and Y.M. Lui, "Rotation, scale, and translation resilient public watermarking for images," *Proc. SPIE*, vol.3971, pp.90-98, 2000.
- [4] M. Kuribayashi and H. Tanaka, "A watermarking scheme based on the characteristic of addition among DCT coefficients," *Proc. ISW2000, LNCS 1975*, pp.1-14, Springer-Verlag, 2000.
- [5] M. Kuribayashi and H. Tanaka, "A new watermarking scheme applying locally the wavelet transform," *IEICE Trans. Fundamentals (Japanese Edition)*, vol.E84-A, no.10, pp.2500-2507, Oct. 2001.
- [6] M. Kuribayashi and H. Tanaka, "Watermarking schemes using the addition property among DCT coefficients," *IEICE Trans. Fundamentals (Japanese Edition)*, vol.J85-A, no.3, pp.322-333, March 2002.
- [7] A. Kusanagi and H. Imai, "An image correction scheme for video watermarking extraction," *IEICE Trans. Fundamentals (Japanese Edition)*, vol.E84-A, no.1, pp.273-280, Jan. 2001.
- [8] W. Bender, D. Gruhl, and N. Morimoto, "Techniques for data hiding," *Proc. SPIE*, pp.164-173, 1995.
- [9] F.A.P. Petitcolas, R.J. Anderson, and M.G. Kuhn, "Attacks on copyright marking systems," *Proc. IH'98, LNCS 1525*, pp.169-190, Springer-Verlag, 1998.
- [10] J.S. Lim, *Two-dimensional signal and image processing*, Prentice-Hall International, 1990.
- [11] S. Nakamori, M. Iwata, and A. Shiozaki, "Watermarking method being robust to geometrical modification using correlation between DCT coefficients and random sequence," *Proc. CSS*, pp.431-436, 2002.
- [12] Z. Duric, N.F. Johnson, and S. Jajodia, "Recovering watermarks from images," *Images, Information & Software Engineering Technical Report*, ISE-TR-99-04, 1999.
- [13] P. Bas, J.M. Chassery, and B. Macq, "Geometrically invariant watermarking using feature points," *IEEE Trans. Image Process.*, vol.11, no.9, pp.1014-1028, 2002.
- [14] S. Voloshynovskiy, F. Deguillaume, and T. Pun, "Multibit digital watermarking robust against local nonlinear geometrical distortions," *Proc. ICIP2001*, pp.999-1002, 2001.



Minoru Kuribayashi received the B.E. degree in 1999, and M.E. degree in 2001, both from Kobe University, Kobe, Japan. Since 2002, he has been a Research Associate in the Faculty of Engineering, Kobe University. His research interests are in digital watermark, information security and cryptography.



Hatsukazu Tanaka was born in Hyogo, Japan, on September 30, 1941. He received the B.E. degree from Kobe University, Kobe, Japan in 1964, the M.E. degree in 1966, and the D.E. degree in 1969, both from Osaka University, Osaka, Japan. He was appointed as a Research Associate in the Faculty of Engineering, University of Osaka Prefecture in 1969. From 1972 through 1987 he was an Associate Professor in the Department of Elec-

trical Engineering, Kobe University. Since 1988 he has been a Professor in the Department of Electrical and Electronics Engineering, Kobe University. From 1980 through 1981 he was a member of the Communication Group of the University of Toronto, Toronto, Ontario, Canada, as a Visiting Scientist. His main work is on the basic theory of Information Engineering such as Information Theory, Coding Theory, Cryptography and Information Security, Image Processing, etc. Dr. Tanaka is a Fellow member of IEEE and a member of IACR.