J-016

Concept of a New Watermark Surviving after Re-shooting the Images Displayed on a Screen

Seiichi GOHSHI,[1] Haruyuki NAKAMURA,[1] Hiroshi ITO,[2] Ryousuke FUJII,[2] Mitsuyoshi SUZUKI,[2] Shigenori TAKAI[3] and Yukari TANI[3]

1 Introduction

Digital technologies have advanced remarkably in the last decade, and most contents are now made and processed digitally, offering many methods to create new contents. However, the technologies also enable contents to be copied illegally and there is no difference between the originals and copies in the market. There are several ways of protecting contents against piracy, such as Digital Rights Management (DRM) that encrypts the content.

Nevertheless, there is no way to protect content against piracy using commercial video cameras to re-shoot screens or TV monitors, and these cameras are becoming more powerful. It is well known that some people go into movie theaters to video the showing, make copies and sell them. Indeed, the Hollywood film industry estimates that such illegal copying costs the industry US $3 billion a year[1].

In Japan, some sellers of these illegal copies have been arrested[2]. These crimes did not exist when analogue copy systems were used, but TV monitors in the home have become larger in the last ten years.

It will soon be possible to pirate pay-per-view TV programs in the home by re-shooting the TV screen, so some means of protection is urgently needed. DRM was developed to prevent contents from being seen by those other than rights holders, but this no longer works because the pirates pay for tickets or are regular subscribers. DRM cannot protect contents against regular members.

Watermarking is a controversial means of content protection. Although it is fragile and does not have any power by itself, it adheres to any copies that are made. Watermarks were developed to conceal information in contents that are copied digitally or by analog means, but most of them cannot prevent re-shooting images displayed on a screen or monitor; only a few ideas have been proposed to prevent such reshooting [3][4].

In this paper we propose a new watermark technology which remains even after re-shooting an image displayed on a monitor. The rest of this paper is organized as follows. Section 2 explains the picture quality of a commercial camera, showing that re-shot content is of marketable quality. In section 3, we explain the concept of our watermark. Finally, section 4 concludes the paper.

[1]NHK, 1-10-11 Kinuta, Setegaya-ku, Tokyo

[2]Mitsubishi Electric Corporation, Information Technology R&D Center, Ofuna, Kamakura, Kanagawa

[3]Mitsubishi Electric Engineering Corporation, Kamimachiya, Kamakura, Kanagawa, Japan

2 Characteristics of Commercial Cameras

As only broadcasters and a few people had good cameras thirty years ago, people could not use them to copy contents by re-shooting. However, the performance of commercial cameras has dramatically improved in the last ten years, and they are now small enough to use anywhere and are not expensive. TV monitors including PDP and LCD displays now also offer good picture quality. High-performance cameras and high-definition displays provide an excellent combination for piracy.

We conducted experiments to measure the characteristics of re-shot pictures. Fig. 1 shows the measurement apparatus, which consists of a signal generator, an oscilloscope, a CRT monitor, a commercial camera and signal format converters. The sweep signal ranges from 200 kHz to 5.75 MHz. The sweep signal is generated and transmitted to the oscilloscope via route 1. Another sweep signal is transmitted to the oscilloscope via the re-shot route of the monitor and the camera, which we call route 2. Fig. 2 shows the sweep signal given by route 1 and Fig. 3 shows the sweep signal given by route 2. They are the original picture and the re-shot picture, respectively.

The characteristics of route 2 are clearly worse than those of route 1. However, the picture quality produced by route 2 is not so bad. The picture quality of normal moving images is shown in reference[5]. This quality is sufficient to allow piracy in movie theaters, but in the near future pirates will be able to copy contents in their own homes. Therefore, new technologies to protect contents against such piracy are needed. DRM and encryption systems do not offer sufficient security against these illegal copies, so this situation is a pirate's paradise.

We propose a new watermark technology that survives after re-shooting the images displayed on a monitor. This approach is also useful for preventing piracy in movie theaters.

3 The Concept

3.1 Watermark Embedding

We assume video images $f(x, y, t)$ as three-dimensional signals, where x denotes the horizontal axis of the screen or monitor, y the vertical axis, and t the time axis. We also assume $g(x, y, t)$ as hiding information in the moving images, and x, y, t are the same as above. $g(x, y, t)$ must satisfy the following conditions.

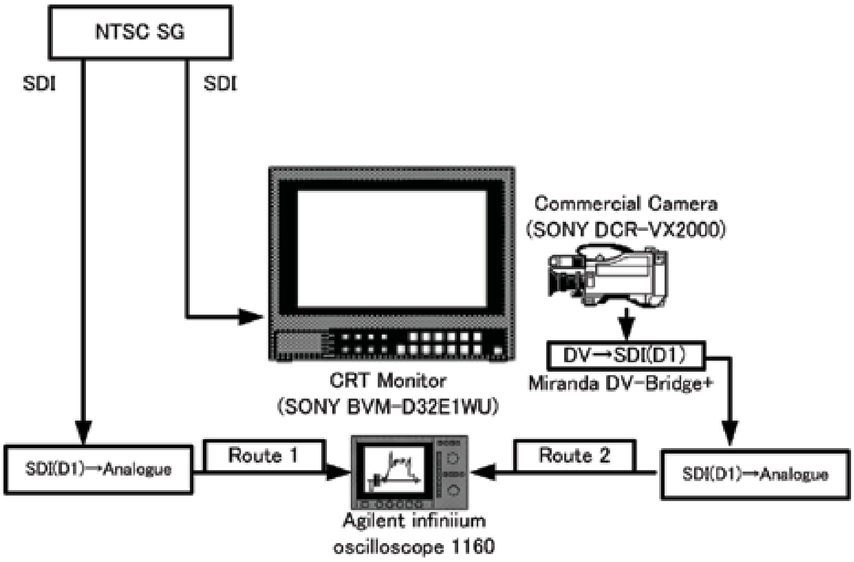

Figure 1: System to Measure the Signal Characteristics

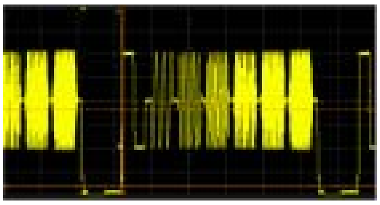

Figure 2: Original Sweep Signal

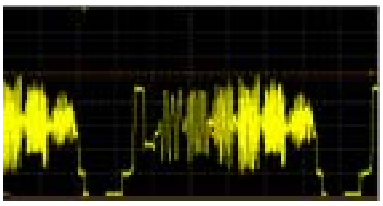

Figure 3: Re-shot Sweep Signal

- $g(x, y, t)$ has very low frequency signals compared with moving images $f(x, y, t)$
- $g(x, y, t)$ must satisfy the following equations:

$$g(x, y, t) = g_1(x, y)g_2(t) \qquad (1)$$

$$\int_0^B \int_0^A g_1(x, y)dxdy = 0 \qquad (2)$$

where, A denotes the width of the image and B the height of the image. Examples of $g(t)$ functions are $\sin x$, wavelet functions and so on.

The moving picture which has embedded information can be written as follows:

$$f(x, y, t) + g(x, y, t) \qquad (3)$$

where, $|g(x, y, t)| \leq 2$. In our approach, the watermark is embedded in only luminance signals. When $|g(x, y, t)| \geq 3$, degradation caused by the watermark becomes visible in some areas of images, which will be discussed in reference[5].

3.2 Watermark Detection

Moving images $f(x, y, t)$ can be expressed as follows:

$$f(x, y, t) = f_{DC}(t) + f_{AC}(x, y, t) \qquad (4)$$

where, $f_{DC}(t)$ denotes DC elements of images and $f_{AC}(x, y, t)$ denotes AC elements. We obtain the following expression from equation (3) for watermark embedded moving images:

$$f_{DC}(t) + f_{AC}(x, y, t) + g(x, y, t) \qquad (5)$$

where, $f_{DC}(t)$ denotes the DC value of time t. We assume one more condition: that $f_{AC}(x, y, t)$ satisfies the following equation if the period of integration is sufficiently long:

$$\int_{-t_0}^{t_0} f_{AC}(x,y,t) g_2(t) dt \approx 0 \quad (6)$$

where, $-t_0$ and t_0 denote the period of time. Although there is no $g_2(t)$ that satisfies equation (6) for all moving images, we can choose several $g_2(t)$ candidates depending on images and we embed a watermark only into images that satisfy this condition. According to our experiments, many moving images satisfy equation (6) if we choose an appropriate value of $g_2(t)$ and an appropriate integral period. This aspect needs further research.

Here, we obtain the product of equation (5) and $g(x,y,t)$, and integrate them. The integral periods must be sufficiently long to satisfy equations (2) and (6).

$$\begin{aligned} &\int_{-t_0}^{t_0}\int_0^B\int_0^A (f_{DC}(t) + f_{AC}(x,y,t) \\ &\qquad + g(x,y,t))g(x,y,t))dxdydt \\ &= \int_{-t_0}^{t_0} f_{DC}(t) g_2(t) dt \int_0^B\int_0^A g_1(x,y) dxdy \\ &+ \int_0^B\int_0^A g_1(x,y) dxdy \int_{-t_0}^{t_0} f_{AC}(x,y,t) g_2(t) dt \\ &+ \int_{-t_0}^{t_0}\int_0^B\int_0^A g^2(x,y,t) dxdydt \quad (7) \end{aligned}$$

Hence, the first term and the second term of equation (7) equal zero; only the third term has some limited value as follows:

$$\int_{-t_0}^{t_0}\int_0^B\int_0^A g^2(x,y,t) dxdydt \neq 0 \quad (8)$$

If we choose an appropriate threshold value, we will be able to judge whether the moving images contain embedded information $g(x,y,t)$ or not.

We would report an experimental result of two dimensional signal, $g(x,y)$ in reference [5]. Three-dimensional $g(x,y,t)$ will be examined in a future study. When we embed some information into moving images, $\sin x$ is used to embed $+1$ and $-\sin x$ for 0. The integration period of x should be from 0 to 2π. The third term of equation (7) becomes as follows when $\sin x$ is embedded:

$$\int_0^{2\pi} \sin x \sin x dx = \pi \quad (9)$$

If $-\sin x$ is embedded, The third term of equation (7) becomes as follows:

$$\int_0^{2\pi} (-\sin x) \sin x dx = -\pi \quad (10)$$

We can thus detect embedded information by these methods. Although there are several assumed conditions, we will give proofs that are valid in normal moving images in the next section.

4 Conclusion

In this paper we described the principle of a new watermark scheme which survives re-shooting of the images displayed on a screen. The approach meets several requirements such as robustness and picture quality.

Further studies will be needed in order to use this approach in practical systems. The next step is to probe the validity of this method by experiments.

A watermark itself cannot protect contents, but is the last defense to prevent illegal copying. Re-shooting of TV monitors to copy contents will soon become possible. We hope that these technologies will be studied and improved in order to protect copyrighted material so that the content business will have a bright future.

References

[1] http://www.sarnoff.com/news/

[2] http://www.nikkei.co.jp/news/shakai/20050221AT1G2101521022005.html (in Japanese)

[3] Jaap Haitsma, Ton Kalker, "A Watermarking Scheme for Digital Cinema", Proceedings of IEEE International Conference on Image Processing (ICIP), (2001) 487–489

[4] Jaap Haitsma, Ton Kalker, "On Digital Cinema and Watermarking", Security and Watermarking of Multimedia Contents, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 5020 (2003), pp. 526-353

[5] Haruyuki Nakamura, Seiich Gohshi, Ryousuke Fujii, Hiroshi Ito, Mitsuyoshi Suzuki, Shigenori Takai and Yukari Tani, "Fundamental Experiments of a New Watermark Surviving after Re-shooting the Images Displayed on a Screen", FIT2005