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Robust Audio Watermarking Algorithm

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Abstract

In this paper, we propose an adaptive digital audio watermarking algorithm. The algorithm uses the local properties of an audiosignal to satisfy the properties of human auditory system. The efficiency and robustness of proposed algorithm is illustrated by examples of random attacks with various intensities and compression attacks in the spectrum domain.

1. Introduction

Nowadays development of digital technologies has facilitated processes of reproduction and distribution of multimedia content. Alongside with obvious utility, such development has created equal opportunities for both a manipulation the data on the lawful bases, and non-authorized use. Hence, there is a necessity of copyright protection of digital production from the non-authorized copying, distribution, and sometimes from ill-intentioned distortion of the information.

Last years the problem of copyright protection of multimedia production has drawn attention of scientists and businessmen all over the world. The most promising decision of this problem represents application of methods of embedding of some secret information into the data, which allows, if necessary, finding out the fact of infringement of copyright. Such embedded information, named in the scientific literature as digital watermark, completely characterizes the author of the given product and confirms the belonging of the product to this author.

The watermarking algorithms are successfully applied to protection of time-dependent data (audiosignals), spatially distributed data (motionless images) and temporarily - spatial data (videos).

Starting from requirements of efficiency, the watermarking procedure has to be steady against attempts of various manipulations with a signal or its removal from the protected object without essential distortion of the object. These attempts usually come to the application of well-known methods of signal and image processing, e.g. filtration, compression, size changing, noising, etc. One can find in [1-3] detailed enough description of these and other kind of attacks to protected multimedia information.

Algorithmic aspects of protection of the digital information are rather various. They not only cover all spectra of methods of processing of the information, but also provide the protection of the information in various important appendices, including legal aspects of these problems [4]. In particular, many approaches and algorithms, despite of distinction in mathematical representation of protected objects, are suitable for both image and signal. However, also there exists certain specificity in the application of these methods, connected with the type of a data

carrier and distinction in the problem setting. For example, an image as bidimentional spatial signal, gives more opportunities for its distortion, than a time-dependent one-dimensional signal. Really, without effort it is possible to subject image to geometrical transformations such as turn, affine transformation, non-uniform scaling etc. while the audiosignals undergo to the above mentioned attacks only partly. Therefore development of watermarking algorithms for one-dimensional signal is basically observed in the spectral area, where high efficiency showed the methods connected to the standard of MP3-compression and wavelet-analysis. However, we must note that the development of effective watermarking algorithms of audiosignal in the spatial area is far from exhaustion of all opportunities and continues to remain in the focus of interest of the researchers.

This in many respects is promoted by wide use of well investigated properties of the human auditory system (HAS), allowing to develop special watermarking algorithms, which allow the imperceptibility of watermark and possible distortion of origin signal for HAS [5].

In this paper, we propose a novel watermarking algorithm in time domain, and show its robustness against random attacks.

The idea of algorithm is borrowed from [6], in which the adaptive approach to embedding procedure of binary watermark in a gray scale image is investigated. In view of enough high robustness of the algorithm used in the specified paper, and its simplicity it is interesting to develop its analogue for an audiosignal and to investigate its robustness to attacks, typical for this case.

2. Description of watermarking algorithm

Let the discrete audiosignal S have length N, and consist of a sequence

$$s(i);\ i = 0,1,\ldots,N-1 \qquad (1)$$

We consider a binary watermark W, so we denote a sequence, which will be embedded in an audiosignal, by $w(k)$, $k = 0,1,\ldots,K-1$, where K - the number of elements $w(k) \in \{0,1\}$. The sequence $w(k)$ can be received from an original object, by hashing, for example, of their consideration order. In the present paper these hashing methods will not be considered. We split the sequence (1) into K segments of identical length N_K, assuming, for distinctness, that $N = K \times N_K$, and denote the elements of (1), which belong to k^{th} segment by

$$s_k(j);\ k = 0,1,\ldots,K-1;\ j = 0,1,\ldots,N_K$$

The operator of watermark W embedded in an audiosignal S we denote by $E_+(S,W,\alpha)$, where $\alpha \geq 0$ is named in the literature as gain parameter. As a result of action of the operator of embedding we get the new signal $S_W = E_+(S,W,\alpha)$ at which watermark W is present with parameter of embedding α.

Let us note that at the fixed value α different watermarking algorithms show different properties, therefore one of the major problems of digital protection of the information is development of watermarking algorithms having sufficient robustness to various type of attacks. Under term "attack" we understand a transformation X of a signal S_W in result of which it turns to a signal $S_{W,X}$, which can differ from the signal S_W.

Procedure of watermark extraction from the attacked signal $S_{W,X}$ is based on the operator $E_-(S_{W,X},S,W,\alpha)$. As a result of application of extraction operator we will receive, as a rule, the deformed image $W_X = E_-(S_{W,X},S,W,\alpha)$ with respect to the initial one.

Nowadays the general methods of construction of embedding E_+ and extraction E_- operators do not exist. However there is rather extensive scientific literature on research of concrete algorithms, with reference to rather various problems of information protection and according to the certain requirements.

In the present paper, we follow the approach applied in [5], an algorithm of watermarking is proposed.

Step 1. The initial signal S of length N splits into K segments of identical length M.

Step 2. Average m_k and deviation d_k are determined for all segments, $k = 0,1,...,K-1$. The file of average values $\{m_k; k = 0,1,...,K-1\}$ is remembered for further use at watermark extraction.

Step 3. Values $s_k^{'}$ of an audiosignal S_w with embedded watermark W for all $k = 0,1,...,K-1$; $j = 0,1,...,N_K$ are calculated by the following formula

$$s_k^{'}(j) = s_k(j) + (-1)^{1-w(k)} \alpha d_k, \tag{2}$$

where α is a preliminarily chosen positive number.

At presence of attack X on a signal (2) the new signal is received as follows

$$S_{w,x} = \{s_w^{'}(i); i = 0,1,...,N-1\}, \tag{3}$$

from which it is necessary to take earlier embedded watermark (or that remained after attack).

The watermark extraction algorithm consists of the following steps:

Step 1. The signal $S_{w,x}$ of length N splits into K segments of identical length M (with the same values of parameters N and K which were used at embedding procedure).

Step 2. The averages $m_k^{'}$ are determined for all received segments,

Step 3. For every $k = 0,1,...,K-1$ values the averages m_k and $m_k^{'}$ are compared. If $m_k^{'} > m_k$, we accept $w_{x,k} = 1$, otherwise $w_{x,k} = 0$. Thus, $W_x = \{w_{x,k}; k = 0,1,...,K-1\}$ we accept for the extracted watermark.

Application of described algorithm should be accompanied by the standard operations, allowing the estimating of a distortion degree of an initial signal because of embedding procedure impact, and also a divergence of extracted watermark from the original. In the first case the distortion should be imperceptible for HAS, and in the second should allow to distinguish clearly the information latent in the signal. For estimating the divergence of signals in the specified cases the peak signal to noise ratio (PSNR) is applied.

3. Experiments

The effectiveness of proposed watermarking algorithm was checked up by a series of experiments with real signals and a binary watermark

There were chosen well-known pieces of music as protected objects, taking into account necessity and an opportunity for a competent person of parallel estimating of quality of the signals received after transformations. The results received for a signal, 5-th symphony of Bethoven appropriate to an initial fragment (in a format *.wav), having length in 1 Mb are below resulted. The Watermark is shown in Table 1 (see the column at $\sigma = 0$). The value of parameter α was varied within the wide limits. PSNR between the signal - original and a watermarked signal at $\alpha = 0.01; 0.05$ was equal to 47 dB and 32 dB correspondingly. We see that the distortion of a signal owing to embedding in the specified watermark is low enough. It is confirmed also by direct listening of a reproduced audiosignal.

Robustness of the proposed algorithm was checked up also at two kinds of attacks: a) random attacks, which were characterized by imposing on a signal of additive normal noise at a

variance σ; b) compressing attacks by using the DCT procedure with cutting the "tail" of spectrum. Experiments with various values of parameter σ and compression ratio p were carried out. In Table 1 extracted watermarks corresponding to certain values of σ and PSNR between the embedded and extracted watermarks are given. We can note that the proposed watermarking algorithm is robust at specified random attacks for a small enough value of α.

σ	0	0.8	1.0	1.2	1.4
Extracted watermark					
PSNR, dB	∞	18.7	15.1	12.9	11.4

Table 1. Dependence of robustness of the watermarking algorithm on parameter σ at $\alpha = 0.01$.

Compression ratio p	0	0.05	0.25	0.75	0.85
Extracted watermark					
PSNR, dB	∞	16.4	16.3	12.7	9.7

Table 2. Dependence of robustness of the watermarking algorithm on parameter p at $\alpha = 0.05$.

In Table 2 the corresponding results of robustness at compression ratio p are shown which means the ratio of number of spectrum coefficients being used at compression to its general number. The visual comparing of extracted watermarks with the embedded one allows to recognize it confidently.

Conclusions

The results of present paper show that the proposed watermarking algorithm doesn't damage the original signal in such a way as to be noticed visually, so it satisfies the main requirement of watermarking procedure to be unnoticed. Moreover, the algorithm is robust enough at random and compression attacks. So the algorithm is correct and can be used for protection of audiosignals by embedding in binary watermarks of considered kind.

References

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Լսաազդանաշաևի ջրանշման կայուն ալգորիթմ

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Ամփոփում

Հոդվածում առաջարկվել է լսաազդանշանի ջրանշման ադապտիվ թվայնացված ալգորիթմ: Այն հենված է լսաազդանշանի տեղային հատկությունների օգտագործման վրա և բավարարում է մարդու լսողական համակարգի հատկություններին: Առաջարկված ալգորիթմի արդյունավետությունը և կայունությունը ցուցադրվել է տարբեր ուժգնության և պատահական նույթի հարձակումների, ինչպես նաև ազդանշանի սպեկտրի տիրույթում սեղմման օրինակների վրա: