EVALUATING REGIONS FOR DIGITAL WATERMARKING WITH PIXEL IMPACT FACTOR AND QUANTIZATION IN SPATIAL DOMAIN

Cezary Żurawski
Politechnika Łódzka, Wydział Fizyki Technicznej, Informatyki i Matematyki Stosowanej, Instytut Informatyki

Abstract. In this article I propose a novel usage of Pixel Impact Factor model to estimate regions for embedding digital watermark in image. Watermarking is performed in spatial domain, with usage of quantization methods. Using different quantization levels allow me to introduce relationship of Pixel Impact Factor and watermark capacity.

Keywords: digital watermarking, pixel impact factor, invisible watermarks, watermark capacity

WYSZUKIWANIE REGIONÓW DO OSAĐENIA ZNAKÓW WODNYCH Z WYKORZYSTANIEM ‘PIXEL IMPACT FACTOR’ ORAZ KWANTYZACJI W DZIEDZINIE PRZESTRZENNEJ

Streszczenie. W tym artykule proponuję nowe podejście do wyszukiwania regionów do osadzania znaku wodnego w obrębie. Osadzanie wykonywane jest w dziedzinie przestrzennej, z użyciem metod kwantyzacji. Użycie różnych poziomów kwantyzacji pozwala wskazać na związek pomiędzy współczynnikami ‘Pixel Impact Factor’ oraz pojemnością cyfrowych znaków wodnych.

Słowa kluczowe: cyfrowe znaki wodne, niewidoczne znaki wodne, pojemność cyfrowych znaków wodnych

Introduction

Digital watermarking [10] is a field of science being still under rapid development. The basic purpose of digital watermarks is to provide copyright protection for intellectual property that’s in digital format. Digital watermarks can be measured and described by many parameters: effectiveness, fidelity, payload, redundancy, robustness, blindness of algorithm, capacity and security [1, 5]. In this work I will take into consideration only fidelity, robustness and capacity.

Fidelity [11] is one of the most important parameters for digital watermarking systems embedding invisible watermarks. This is when embedder does not want to interfere and distort original content. Fidelity is responsible for information how much difference is between copy and original image.

Robustness [2] is a parameter corresponding resistance to attacks on watermarked content. These attacks can be intended or unintended. For images these can be, for example, filtering, cropping, rotating, color changing and more. Higher robustness is better though it helps to extract watermark from attacked content.

Capacity [6] is a parameter telling how much information can we put as watermark. More information causes bigger distortion for watermarked content. But embedding more information could make robustness higher, for example using spread spectrum technic to replicate watermark inside watermarked content.

Watermarking systems parameters depends on each other. For example, less capacity means less information that we can use to watermark and it means that this watermark is less robust. These dependency can be presented as triangle (Fig. 1).

![Fig. 1. Digital watermarking parameters dependency triangle](image)

According to applications, watermarking systems balance between these parameters [7].

1.1. Background

In earlier work [12] authors proposed a Pixel Impact Factor method for improvement of fidelity measures.

Pixel Impact Factor is based on standard deviation calculated for block built around each pixel in image. Default block size is 9x9 pixels where subject pixel is in the center of block. The main idea is to use standard deviation as measure of importance of this actual pixel in fidelity measure. The highest Pixel Impact Factor (PIF) means the lowest impact on fidelity measure in this actual point of image [12] (Fig. 2).

![Fig. 2. Less (high Pixel Impact Factor, PIF = 1,131) and more (low Pixel Impact Factor, PIF = 0,059) distorted blocks with evaluated pixel in center](image)

Pixel Impact Factor is prescribed as

$$PIF = \frac{1}{\sigma_{B(i,j)}} \tag{1}$$

where $\sigma_{B(i,j)}$ is standard deviation of block B build around pixel with coordinates in image i,j. Standard deviation can be prescribed as

$$\sigma_{B(i,j)^2} = \frac{\sum_{x=1}^{M} \sum_{y=1}^{N} (x_{B(i,j)} - \mu_{B(i,j)})^2}{(M*N)-1} \tag{2}$$

where: $M, N$ – block dimensions in pixels, $x_{B(i,j)}$ – block pixel value, $\mu_{B(i,j)}$ – mean value of pixels in block, $i,j$ – coordinates of pixel in image, $x, y$ – coordinates of pixels in block. Mean value can be prescribed as

$$\mu_{B(i,j)} = \frac{\sum_{x=1}^{M} \sum_{y=1}^{N} x_{B(i,j)}}{M*N} \tag{3}$$

1.2. Embedding watermark

Embedding watermark into image always distorts its structure [3] (Fig. 3). Digital watermark can be considered as a noise.
Fig. 3. Embedding watermark schema

It can be prescribed as

\[ c_{w} = c_{o} + w \]  \hspace{1cm} (4)

where: \( c_{o} \) – original image, \( w \) – watermark, \( c_{w} \) – watermarked image.

For embedding invisible watermark, the most important is to achieve very high fidelity of original and watermarked image.

\[ \text{similarity}(c_{o}, c_{w}) \approx 1 \]  \hspace{1cm} (5)

where \( \text{similarity} = 1 \) means that images are identical. Maximizing similarity is a goal author wants to achieve. At the same time author needs to keep reasonable capacity and robustness of watermark.

1.3. Watermarking domains

Four of the mostly used watermarking domains are [5]:

- spatial domain,
- wavelet transform domain,
- cosine transform domain,
- Fourier transform domain.

Watermarking in spatial domain means that we directly change pixels in image. One of the very first watermarking algorithms was changing least significant bit (LSB) in pixels of image [10]. Using transform domains means that transform coefficients are used to embed watermark [9]. Image is transformed, then specified coefficients are modified and transform is reversed. Using transforms domains does not allow to control direct place where watermark is embedded (opposite to spatial watermarking scheme) [4].

1.4. Perception of distortion

Considering Human Visual System (HVS) there is difference of perception of distortion inserted into the same image in different areas [1]. As an example author uses well known Lena image (Fig. 4).

Fig. 4. Comparison of distortion in different areas. Left image – highly visible distortion. Right image – hardly noticeable distortion

Both images are distorted with the same mask (100px by 100px randomly generated AWGN). Distortion on left image is much more visible than on the right [11]. Because it is the same distortion it can be treated as watermark with capacity parameter constant. So embedding the same watermark in different regions we can influence fidelity of watermarked image to original one.

\[ \text{capacity} = \text{const.} \]  \hspace{1cm} (6)

\[ \text{fidelity}(c_{o}, c_{w}) = \text{maximum} \]  \hspace{1cm} (7)

This leads to idea of finding the best region to embed watermark in terms of fidelity.

2. Assessing regions for digital watermark

Considering perception of distortion mentioned in 1.4 I propose a novel method to assess region for digital watermark embedding. This method is based on Pixel Impact Factor. Method consists of two steps:

1) Calculate PIF matrix for image,
2) Quantize PIF matrix.

Different quantization levels allows to use different strength for watermark embedding though it impacts capacity and fidelity. It is important to balance this parameters.

2.1. Calculate PIF matrix

Algorithm for calculation PIF matrix is designed as presented on diagram (Fig. 5).

Fig. 5. Diagram calculating Pixel Impact Factor matrix

2.2. Quantize PIF matrix

As a result of calculations completed in previous step I receive a Pixel Impact Factor coefficients matrix. These values are \(<0, 134.3968>\) so Pixel Impact Factor values are \(<\infty, 0.0074>\). To achieve regions evaluation I use uniform quantization. This is achieved by mapping floating-point value to an integer value. Integer value is determined by quantization level value. The input range is divided into \(2^{n}\) evenly spaced intervals, where \(n\) is quantization level. Input entries are first quantized according to subdivision of the input range, and then mapped to one of \(2^{n}\) integers. Algorithm of quantization is presented on diagram (Fig. 6).

Example of part of quantized matrix is presented on next figure (Fig. 7).
2.3. Algorithms complexity

Time complexity of both algorithms is linear O(n) and it depends on number of pixels in image. Considering colorful images the overall number of primitive calculations have to be multiplied accordingly. Because these calculations are independent, they can be done on many cores simultaneously. This trait makes use of GPU justified [8].

3. Results

I tested proposed method with well-known Lena image. As a result I managed to evaluate, through quantization matrix, regions to embed digital watermark. To better visualize, evaluated regions are presented as images (Fig. 8 – Fig. 12). Black color is used to present better regions to embed watermark, while white color opposite.
4. Conclusions

Embedding invisible watermark is a very interesting technique in terms of protecting copyright laws. But embedding watermark is distorting image and it is very important to find regions where watermark embedding is maximally invisible.

In this article I propose novel method of evaluating regions for embedding digital watermark in spatial domain, especially for invisible digital watermarks. This method is based on calculating Pixel Impact Factor matrix and quantizing this matrix using uniform quantization. Also this method allows to associate watermark visibility and capacity. Higher level of quantization indicates lower quantity of pixels to embed watermark and higher level of invisibility, because of use lower values of Pixel Impact Factor.

5. Future Work

Using Pixel Impact Factor to evaluate regions for embedding invisible digital watermarks is a very promising method. In future work it is planned to compare Pixel Impact Factor model to different models using Human Visual System model. Comparing and extending Pixel Impact Factor model can improve usability of Pixel Impact Factor model for using in digital watermarking systems and other systems using digital signal processing.

Bibliography

[1] Bender W., Gruhl D., Morimoto N., Lu A.: Techniques for data hiding. IBM Systems Journal, vol. 35, no. 3-4, 1996, 313-336.
[2] Burch C., Funk W., Wohlhusen S.: Digital watermarking: from concepts to real-time video applications. Computer Graphics and Applications, IEEE, Jan/Feb 1999, 25-35.
[3] Cox I.: Digital Watermarking and Steganography. Morgan Kaufmann Publishers, 2008.
[4] Cvele C.: Algorithms for Audio Watermarking and Steganography. University of Oulu, Oulu 2004.
[5] Lipiński P.: Odporne cyfrowe znaki wodne w obrazach. Akademicka Oficyna Wydawnicza EXIT, Warszawa 2013.
[6] Manaf A. A., Mahmoud S. S.: High Watermarking Capacity Based on Spatial Domain Technique. Information Technology Journal, 10, 2011, 1367-1373.
[7] Shih F. Y.: Digital Watermarking and Steganography: Fundamentals and Techniques. CRC Press, Inc., 2007.
[8] Skłodowski P., Zorno W.: Movement Tracking in Terrain Conditions Accelerated with CUDA. Proceedings of the 2014 Federated Conference on Computer Science and Information Systems, 2014, 709-717.
[9] Stołecek J., Lipiński P.: Improving watermark resistance against removal attacks using orthogonal wavelet adaptation. Proceedings of the 38th international conference on Current Trends in Theory and Practice of Computer Science, Berlin, Heidelberg, 2012.
[10] Tirkel V. R.: Electronic Water Mark. Sydney, 1993.
[11] Zurawski C.: Analysis of Pixel Impact Factor-Based Image Fidelity Measure In Correlation With Subjective Measurement. XV International PhD Workshop, 2013.
[12] Zurawski C., Skłodowski P.: Standard Deviation-Based Image Fidelity Measure for Digital Watermarking. XIV International Conference - System Modelling and Control, Łódź, 2013.

M.Sc. Cezary Zurawski
e-mail: cezary.zurawski@dokt.p.lodz.pl

Author is working on his PhD on the field of digital watermarks. In 2012 he defended his MA thesis entitled “Digital audio watermarking” in Institute of Information Technology, Technical University of Łódź, Poland.