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Image Content Detection Method Using Correlation Coefficient between Pixel Value Histograms

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Abstract. An extraction method for searching for unauthorized copies of an image on the Internet is required in image search to make use of digital watermarks. In this paper, we propose an efficient two-stage image search method for extraction of illegal copies of a target image. The first stage is a pre-search, which searches for candidate of illegal images by some simple method. The next stage is the main search, which extracts embedded copyright information from the candidate and decides whether the image is an illegal copy of the target. In addition, we propose a simple image search method which uses the correlation coefficient between pixel value histograms of images as a pre-search method. The proposed pre-search method is useful because the proposed method is possible to combine with the current extraction technologies of embedded information. The performance of the proposed pre-search method is evaluated through computer simulations.

Keywords: Digital watermark, Image search, Correlation coefficient, Pixel value histogram

1 Introduction

Recently, the generation and transcription of digital content including images became sufficiently easy that it can be done by individuals, due to the high performance and high speed of current personal computers. Moreover, a large amount of content including images are sent and received by individuals, and thus content from/to servers is frequently downloaded and uploaded over the Internet.

The above-described situation, although convenient, also leads to copyright infringement due to unauthorized copying of content by third persons becoming a social problem. Methods to find unauthorized copying from among a large amount of content on the Internet are required. Digital watermark is one such method. The use of watermarks actually consists of two methods: one to embed copyright information in content, and a second to extract particular content from among a larger amount of content. The latter, a method for extracting particular content from among the larger amount of content on the Internet, is similar to existing image search methods.

In general, the object being searched by image search method is in a database. In a general database, multiple feature vectors [1,2] that show the characteristics of particular images are registered. In an instance of an image search, the key word describing a characteristic of the content desired is input, and images for which this key word is included in the feature vector of the database are output as an extraction result.

However, in the case of a digital watermark, it is the Internet and not the database that is searched. Therefore, a key word describing a characteristic of the image cannot be used. Moreover, it is necessary not only to detect similar images but also to extract the embedded copyright information that proves ownership.

Because the above requirement is difficult, methods using key words have been proposed [3,4]. In these methods, a feature vector of content is registered with content in a watermark certificate center for proving ownership. Then, the feature vector of Internet content is extracted, and the feature vector registered at the watermark certificate center is retrieved. If the extracted feature vector matches the feature vector of the particular registered image using the latter feature vector as a key word, an illegal copy has been identified. This method is a reverse search procedure for searching for particular content, not from among content on the Internet, but from that registered at the center.

However, the procedure of the above-described methods is high complexity. Actually, though much research [5-7] on digital watermarks has already been done, only methods for the embedding and extraction of copyright information into/from content are discussed, where as methods for effectively searching for illegal copies from among the large amount of content on the Internet has not been sufficiently considered.

In this paper, to solve the above problem, we propose an efficient two-stage image search method for extraction of illegal copies of a target image. The first stage is a pre-search using some simple method, which searches for illegally copied images as an input candidate for next stage. The next stage is the main search, which extracts embedded copyright information from the candidate and decides whether it is an illegal copy of target image. In addition, we propose a simple image search method which uses the correlation coefficient between pixel value histograms of images as a pre-search method. It is the proposed image search method using this particular proposed pre-search algorithm that is the focus of this paper. We evaluate the extraction performance of this image search method for JPEG compressed images, which use the most common image compression format.

The remainder of this paper is organized as follows. Section 2 presents the proposed two-stage image search method. Section 3 describes the image search method using the correlation coefficient between pixel value histograms. Section 4 describes an image search for JPEG compression images. Section 5 presents the pre-search algorithm for the proposed image search method. Simulation and results are shown in Section 6, and concluding remarks are given in Section 7.

2 Proposed Two-Stage Image Search Method

Fig. 1 shows the proposed two-stage image search method. In the pre-search stage, image content from the Internet is input, and it is investigated whether this content is similar to owned content using a simple method. If the content is not similar, the search process is terminated, and the next image content is investigated. If the content is similar, the image content is output to the main search stage as a candidate of illegal copying. In the main search stage, the embedded copyright information in the image is extracted by a predefined method. When the extracted copyright information indicates the target image, a complaint is sent to the user by a predefined procedure. It is possible to search for illegal copies efficiently because the pre-search stage is simple.

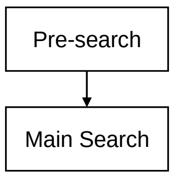

Fig. 1. Two-stage image search method for digital watermarking.

3 Image Search Method Using the Correlation Coefficient between Pixel Value Histograms

It is necessary to extract candidate illegal copies by a simple method in order to extract efficiently from among the large number of images on the Internet. In the process, avoiding missing an illegal copy is more important than avoiding extracting some many images. In addition, robustness to small changes in pixel values is required to avoid omissions because the pixel values of illegal copies may include various noises used to attack the watermarking.

With this in mind, pixel value histograms are used as a feature quantity for image searches because this feature quantity is insensitive to attack by geometric transform, such as rotation and scaling. The correlation coefficient between pixel value histograms normalized by the number of pixels in the image is used to evaluate similarity between two images. The correlation coefficient is defined as follows:

$$r = \frac{\sum_{i=0}^{255}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=0}^{255}(x_i - \bar{x})^2 \sum_{i=0}^{255}(y_i - \bar{y})^2}}, \quad (1)$$

where $x=\{x_i\}$, $y=\{y_i\}$ denote the normalized frequency at pixel value i, and $\bar{x}$, $\bar{y}$ denote arithmetic mean.

Firstly, we verify the correlation coefficient between the original image and a geometrically attacked image as a preliminary experiment. "Lenna" (256x256 pixels, grayscale) is used as a test image, and the geometrically attacked images are transformed by 0.75x or 1.25x scaling or by 15, 30, or 45 degree rotation. Bilinear interpolation is used as the pixel interpolation method in the geometric transform.

Fig. 2 shows the original image and geometrically attacked images, and Table 1 shows the correlation coefficient between these images and the original. From Table 1, the correlation coefficient is high despite the geometric attack. Therefore, it is evident that the correlation coefficient between pixel value histograms is suitable as a feature quantity for image searches involving geometrically attacked images. From the results, the decision threshold for the matching image search is set to 0.95 to consider margin for avoiding missing image match.

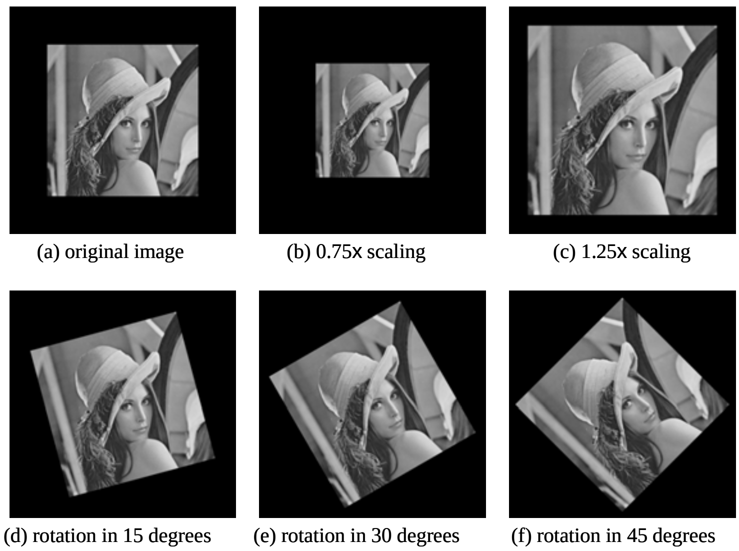

Fig. 2. Original image "Lenna" and geometrically attacked images.

Table 1. Correlation coefficient between original image "Lenna" and geometrically attacked images.

scaling/rotation attack	correlation coefficient
15 degrees for anticlockwise rotation	0.993
30 degrees for anticlockwise rotation	0.994
45 degrees for anticlockwise rotation	0.991
0.75x scaling	0.992
1.25x scaling	0.994
original	1.000

4 Image Search for JPEG Compression Images

Most images on the Internet are compressed by some method for efficient transmission. Hence, it is very important to extract compressed images. JPEG compression is the main coding format worldwide, and so handling JPEG compressed images in particular is considered.

Table 2. Correlation coefficient between original image and JPEG compressed images.

quality parameter	correlation coefficient without histogram smoothing		correlation coefficient with histogram smoothing	
	Lenna	Bridge	Lenna	Bridge
100	0.999	0.998	1.000	0.998
80	0.995	0.272	0.998	0.824
60	0.986	0.287	0.997	0.824
40	0.964	0.288	0.996	0.825
20	0.760	0.279	0.985	0.821

Table 3. Correlation coefficient between JPEG compressed image with quality parameter 60 and JPEG compressed images.

quality parameter	correlation coefficient without histogram smoothing		correlation coefficient with histogram smoothing	
	Lenna	Bridge	Lenna	Bridge
100	0.986	0.322	0.995	0.853
80	0.988	0.990	0.997	0.998
60	1.000	1.000	1.000	1.000
40	0.958	0.990	0.994	0.998
20	0.744	0.987	0.933	0.996

Firstly, we measure the correlation coefficient between an original image and JPEG compressed images as a preliminary experiment. In the experiment, the original image is transformed into a JPEG compressed image using GIMP [8], and the parameter q for image quality control is set from 20 to 100. Table 2 shows the correlation coefficient between original image and JPEG compressed images for "Lenna" and "Bridge" images. The experiment value of left column in Table 2 shows the correlation coefficient when pixel value histogram has been used as it is. From the column in Table 2, the correlation coefficient decreases significantly as JPEG compression image quality is degraded, especially in the case of the "Bridge" image. The reason for this is that JPEG compression causes distinctive changes to the histogram, and the histogram change is large because the pixel resolution of the "Bridge" image is 64 levels essentially.

Therefore, in this paper, two techniques are introduced into the image search as corrective measures for JPEG compressed images. One is N-level smoothing of the pixel value histograms in order to defuse the effect of the histogram changes. By a preliminary experiment, we selected not three-level but five -level with large effect of smoothing. The experiment value of right column in Table 2 shows the correlation coefficient with five-level smoothing histogram. A large effect of smoothing has been achieved. Another proposed technique is to use some quality JPEG compressed images as the standard image instead of the original image.

Table 3 shows the correlation coefficient between the smoothed histograms of JPEG compressed image with quality parameter 60 (for example) and all JPEG compressed images. Here, 60 is median value from 20 to 100. From the table, it is clear that it is possible to extract the match image using both histograms without and/or with histogram smoothing, using the 0.95 decision threshold value from among JPEG compressed images.

5 Pre-search Algorithm for the Proposed Image Search Method

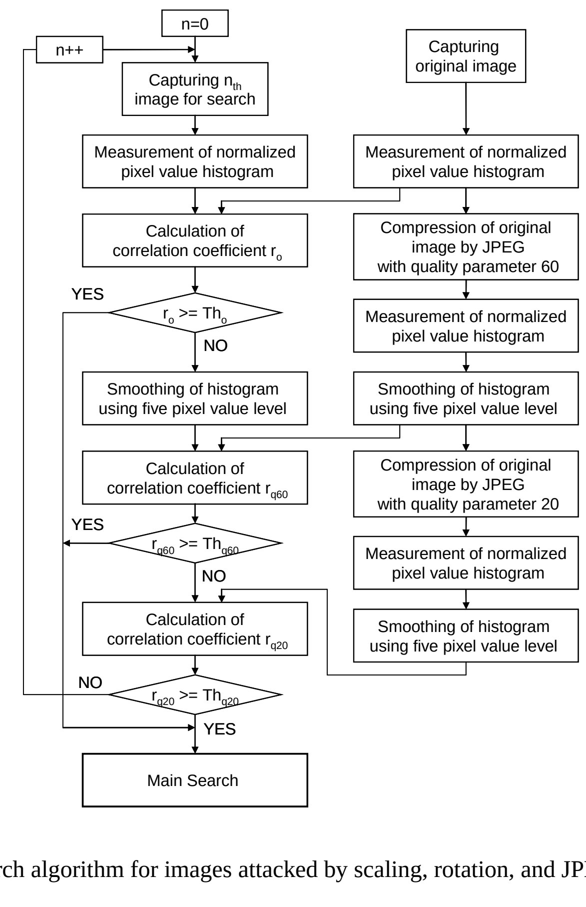

Fig. 3. Pre-search algorithm for images attacked by scaling, rotation, and JPEG compression.

Fig. 3 shows the pre-search algorithm in the proposed image search method.

In the pre-search algorithm, firstly, an image on the Internet is input, and the correlation coefficient r_o between pixel value histograms of the original image and the observed image is calculated. If r_o is Th_o or more, the observed image is extracted as a candidate illegally copied image. The stage to here is effective for attack image of scaling and rotation. If r_o is less than Th_o, the correlation coefficient r_{q60} between the smoothed histogram of the JPEG compressed image with quality parameter 60 and the observed image is calculated. If r_{q60} is Th_{q60} or more, the observed image is extracted as a candidate. If r_{q60} is less than Th_{60}, the correlation coefficient r_{q20} between the smoothed histogram of the JPEG compressed image with quality parameter 20 and the observed image is calculated. If r_{q20} is Th_{q20} or more, the observed image is extracted as a candidate. The obtained candidate is output to the main search. If r_{q20} is less than Th_{20}, the observed image is excluded from the input of the main search. In this paper, Th_o, Th_{q60} and Th_{q20} are set to 0.95.

6 Simulation and Results

The pre-search algorithm in the proposed method is analyzed by computer simulations. In the experiment, 12 images (256x256 pixels, grayscale) from SIDBA, "Airplane", "Barbara", "Boat", "Bridge", "Building", "Cameraman", "Girl", "Lax", "Lenna", "Lighthouse", "Text", and "Woman", are used as test images.

6.1 Identification of Match Image and Extractive Omission

Firstly, we evaluate performance of the match image extraction in the proposed pre-search method using JPEG compressed test images. Table 4 shows the correlation coefficients r_o, r_{q60} and r_{q20} in the pre-search algorithm. The images for which all of r_o, r_{q60} and r_{q20} are less than 0.95 are the omitted images of the extraction process.

From Table 4, the proposed pre-search method extracted the match image for all test images.

6.2 Excessive Extraction

Secondly, we measure the correlation coefficient between different images for evaluation of excessive extraction. In the experiment, a few pairs of "Building" and "Lighthouse" having white bars at the same position at the bottom of the image were extracted as the match image. These images are distinctive images which include too many white pixels in white bar region. The common white pixels cause a significant increase in the correlation coefficient for these images. However, excessive extraction is not as important as extractive omission in the case of illegally copied images.

As a result, the proposed pre-search method was able to identify all images as the match image except for a few excessive extractions.

Table 4. Identification of match image by the proposed pre-search algorithm.

quality parameter	Airplane			Barbara			Boat		
	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}
100	1.000	0.998	0.989	0.999	0.998	0.994	1.000	0.998	0.990
80	0.998	0.999	0.990	0.992	0.999	0.995	0.997	0.999	0.990
60	0.982	1.000	0.990	0.989	1.000	0.995	0.969	1.000	0.990
40	0.931	0.998	0.993	0.981	0.998	0.996	0.885	0.996	0.998
20	0.681	0.990	1.000	0.936	0.995	1.000	0.665	0.990	1.000

quality parameter	Bridge			Building			Cameraman		
	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}
100	0.998	0.853	0.851	1.000	0.999	0.567	1.000	0.990	0.952
80	0.272	0.998	0.996	0.997	1.000	0.582	0.984	0.997	0.964
60	0.287	1.000	0.996	0.997	1.000	0.584	0.960	1.000	0.973
40	0.288	0.998	0.996	0.997	1.000	0.582	0.744	0.995	0.985
20	0.279	0.996	1.000	0.316	0.584	1.000	0.450	0.973	1.000

quality parameter	Girl			Lax			Lenna		
	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}
100	0.996	0.984	0.969	1.000	0.998	0.988	0.999	0.997	0.985
80	0.653	0.999	0.990	0.996	0.999	0.990	0.995	0.999	0.988
60	0.659	1.000	0.991	0.995	1.000	0.993	0.986	1.000	0.989
40	0.505	0.998	0.993	0.991	0.999	0.996	0.964	0.998	0.991
20	0.422	0.991	1.000	0.892	0.993	1.000	0.760	0.989	1.000

quality parameter	Lighthouse			Text			Woman		
	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}	r_o	r_{q60}	r_{q20}
100	1.000	0.998	0.623	1.000	0.997	0.774	1.000	0.998	0.990
80	0.991	0.999	0.644	0.995	1.000	0.811	0.994	0.999	0.992
60	0.989	1.000	0.647	0.996	1.000	0.813	0.993	1.000	0.993
40	0.971	0.999	0.646	0.996	1.000	0.807	0.976	0.999	0.995
20	0.316	0.647	1.000	0.595	0.813	1.000	0.827	0.993	1.000

r_o: correlation coefficient between histograms of the original and JPEG image

r_{q60}: correlation coefficient between the smoothed histograms of the JPEG image with quality parameter 60

r_{q20}: correlation coefficient between the smoothed histograms of the JPEG image with quality parameter 20

7 Conclusions

In this paper, we proposed an efficient two-stage image search method for extraction of illegal copies from among the large number of images on the Internet. In addition, we proposed a pre-search algorithm which searches for candidate illegally copied images using a simple method. The proposed pre-search method is possible to combine with the current extraction technologies of embedded information. Simulation results revealed that the proposed pre-search method provides good performance in the image search for a digital watermark, indicating that the future prospects of the proposed image search method are excellent. In the future, we intend to develop a search method for other types attack of against digital watermarks in images.

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