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Detecting Printed and Handwritten Partial Copies of Line Drawings Embedded in Complex Backgrounds

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Abstract

The partial copy is a kind of copy produced by cropping parts of original materials. Illegal users often use this technique for plagiarizing copyrighted materials. In addition, original parts are not necessarily copied intact but may be modified by various techniques, and embedded into other materials, which make the detection quite difficult. In this paper, we propose a method of copyright protection applicable to partial copies aiming at the protection of line drawings such as comics. In order to cope with handwritten partial copies, we apply local feature matching with a database of copyrighted line drawings. Experimental results show that the proposed method not only performs good for detecting printed copies of line drawings, but also has effectiveness on the detection of handwritten ones, even if partial copies are embedded in complex backgrounds.

1. Introduction

Line drawings are a type of representation of contents that consist of distinct straight and curved lines for describing objects. They are usually monochromatic and without gradations. Among the publications of contents, line drawings, such as comics, logos and graphics, occupy an overwhelming area. Although they are with less color information than photos, line drawing productions are sometimes more valuable due to the cost of their design and drawing. In the case that they are published as printed matter, they can be easily converted into digital images that result in distribution of their illegal copies. Therefore, there is a great requirement for protecting the copyright of line drawings in the form of images.

In practice, illegal users do not always use the whole drawing directly, but attach its part to their own line drawings. In particular, since line drawings consist of lines, it is easy to copy them by hand with some changes from the original ones. Therefore, for their plagiarism detection, we need to consider not only the printed copies of the whole image, but also printed and handwritten partial copies.

There are many methods for protecting the copyright of images. One of them is digital watermarking. Using watermarks, we can embed copyright information into images by slightly changing them. For the case of color images, we can embed enough information in an imperceivable way because such images are highly redundant. Some watermarks have very high level resistance that would not be damaged by geometrical transformations, such as the method by Bas et al. [1] using feature points of images. However, since line drawings are with less redundancy, it is hard to embed information without being perceived.

Another method of protecting the copyright is retrieval, i.e., matching suspicious images with the database of copyrighted images. Because local features of images, such as corners and edges, are stable during the conversions of images, they are usually used for image retrieval. Mikolajczyk et al. [2] have compared various kinds of local features and proved that the SIFT (Scale-Invariant Feature Transform) based descriptors perform best for image retrieval. SIFT is a method to extract the local features proposed by Lowe [3] and has been proved to be invariant to image rotation, scaling, translation, and partial illumination change. Y. Ke et al. have used the PCA-SIFT (Principal Component Analysis SIFT) [4], which is a method to reduce the dimensions of SIFT feature vectors, for near-duplicate detection of images [5]. However, it has not been well studied whether these local features are also effective for line drawing images, especially for handwritten copies.

To detect handwritten partial copies of line drawings, we propose a method of local feature matching by using MSER (Maximally Stable Extremal Regions) [6] as the region detector and HOG (Histogram of Oriented Gradients) [7] as the feature detector. Experimental results show that, as compared to a method with SIFT, the proposed method has similar effectiveness for detection of printed line drawings, and outperforms for detecting handwritten ones. The proposed method has also proven to be robust to rotations and scale transformations in a certain range.

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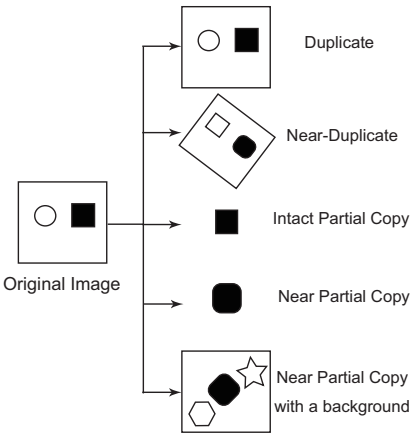


Figure 1. Types of illegal copies.

(a) Crop of original line drawing.

(b) Handwritten copy.

Figure 2. Example of line drawings and its handwritten copy.

2. Task definition

Illegal users usually try to avoid copyright detection by applying various kinds of image processing. As shown in Fig. 1, we classify illegal copies into five types. Duplicates, which are intact copies of the whole image, are the easiest to be detected. By applying image modification to the whole image, illegal copies become not exactly the same as the original ones, which are called near-duplicates. In addition, since some illegal users may just copy interesting parts from the original images, partial copies are created. Partial copies are divided into intact and near partial copies by whether applying modifications to the original images. From the viewpoint of detection, the case of near partial copies with backgrounds is the most difficult problem. In particular, line drawings could be copied easily by handwriting, which can change the image a lot in detail with, for example, removing unimportant parts as illustrated in Fig. 2. It also contains lots of changes in detail, such as changes in arrangement of lines as well as the scale.

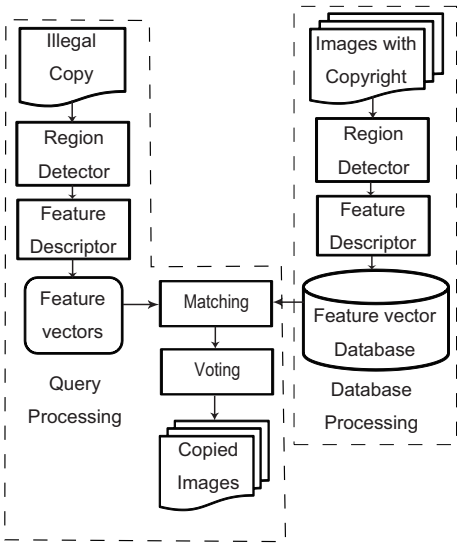


Figure 3. Processing steps.

3. Proposed method

Different types of copies may require different detection methods. However, to make the plagiarism detection system widely applicable, it is required to detect all types by a single method. We propose a method to detect the near partial copies with complex backgrounds, which is the most difficult problem. Certainly, it can also be used for detecting the duplicates and near-duplicates.

3.1. Overview

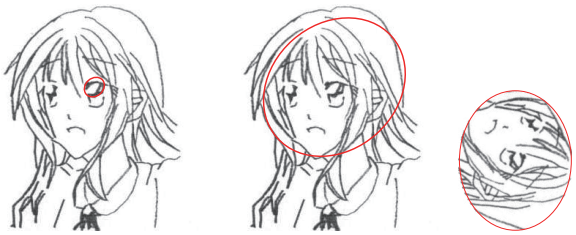
The proposed method is based on local feature matching to detect the partial copies of line drawings. As shown in Fig. 3, the process is divide into two parts.

In the database processing, we store images for copyright protection. By using a region detector, local feature regions(LFRs) are extracted from these images. Then, through a feature descriptor, we obtain local feature vectors from LFRs. Based on the local features extracted from copyrighted images, we build a database of local feature vectors with their image labels.

In the query processing, a suspicious copy is treated as a query. Local feature vectors from the query are extracted by applying the same detector and descriptor. Then, local feature vectors of the query are matched with those in the database using the nearest neighbor search. Through the voting by matched feature vectors, top n images with larger votes would be reported as candidates of the original image.

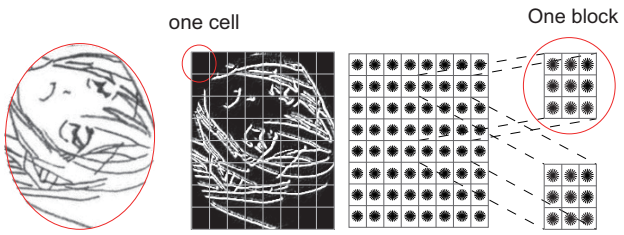
3.2. Region detector and feature descriptor

In order to obtain robust regions under various transformations including handwriting copy, we propose to ap-



(a) MSER. (b) Magnified MSER. (c) LFR.

Figure 4. Processing of local feature regions.



(a) LFR. (b) Cells. (c) Blocks.

Figure 5. Region instruction of HOG features.

ply MSER [6] as the region detector. By using multiple scaled measurement of these regions, they establish correspondences between a pair of images taken from far different viewpoints.

MSERs are the maximally stable regions, in which the intensities of all pixels are greater or smaller than their boundaries. By diagonalizing the covariance matrix of MSERs, we can get some ellipse regions from the image. MSERs have been proved to be affine invariant and stable under photometric changes. These are good properties for extracting similar regions from handwritten copies, because the handwriting may change the thickness and intensity of lines. Since the handwriting may change the images a lot in detail, we filter the regions with small size, which are the most likely to be extracted from those unstable parts. To make the features more discriminative, we need to let the ellipse regions contain more information. Therefore, as shown in Fig. 4(b), we magnify the ellipses M times. Finally, we normalize these regions by rotating the long axis of ellipse parallel to the y axis of the image as shown in Fig. 4(c). Here, we have invariant LFRs to rotations.

To extract stable feature vectors from handwritten line drawings, we apply HOG as the feature descriptor. HOG was proposed by Dalal et al. [7] for human detection. The basic idea of HOG is that local object appearance and shape can often be characterized rather well by the distribution of edge directions, even without precise knowledge of the edge positions. Because handwritten drawings are not the same as the original one precisely, HOG would be a good choice for detecting handwritten copies.

In the proposed method, feature vectors of HOG are extracted from all LFRs. As shown in Fig. 5(b), first calculate the gradient strength and the direction at each pixel, and divide LFP into 8×8 cells evenly. Then, as shown in Fig. 5(c), the gradient directions are quantized into 9 bins. Thus we get a vector of 9 dimensions for each cell by calculating the gradient direction histogram based on the gradient strength. Next, combine the cells into overlapped blocks as 3×3 cells per block. The vector for each block is composed of vectors of cells, and the vector of LFR consists of all normalized vectors of blocks. Therefore we extract a vector of $9 \times 3 \times 3 \times 6 \times 6 = 2916$ dimensions.

3.3. Matching and voting

Because the number of feature vectors stored in the database is quite large, we need to speed up the matching. For this purpose, we employ ANN(Approximate Nearest Neighbor search) [8] to detect the nearest feature vectors. ANN is a method to find the approximate nearest neighbor by using the k-d tree. To increase the matching speed, ANN searches the feature space shrunk by the factor $1/(1+\varepsilon)$. Therefore, it may miss the nearest vector.

A serious problem of matching is that the line drawings contain similar parts which cause considerable erroneous matching. In order to reduce the influence of erroneous matching, we apply the screening with the distance ratio defined as follows:

$$\frac{d(\boldsymbol{q}, \boldsymbol{p}_1)}{d(\boldsymbol{q}, \boldsymbol{p}_2)} < T$$

where $\boldsymbol{q}$, $\boldsymbol{p}_1$ and $\boldsymbol{p}_2$ are a feature vector of the query, its nearest and the second nearest feature vectors in the database, respectively, and T is a threshold. Only the matched vectors satisfying the above equation are employed for voting. Through the voting of matched vectors for each image, we can get a list of images ranked by the similarity. Finally, the top n images are reported as candidates.

4. Experiments

4.1. Conditions

We prepared 1002 images (about 700×1100 pixels jpeg files) from 7 comics for our database. The number of LFRs (and thus feature vectors) for one image was 638 on average. For making query images, we made 101 fragments (400×400 pixels) from the database, such as a part of human faces and bodies, buildings, and so on. Then, they

are converted into images by the following two ways: (a) printed and scanned these copies, (b) drew them by hand and scanned the handwritten copies. The size of scanned copies were $3/4$ (300×300 pixels) of the original parts. With these partial copies, we made different query images for different experiments by applying some transformations to them or embedding them into complex backgrounds. All experiments were done with a computer with Opteron 2.4GHz CPU and 128GB memory. The parameters for the proposed method were: $M = 6$, $\varepsilon = 10$, $T = 0.95$.

4.2. Experiment 1

First, we tested the effectiveness of the proposed method on printed and handwritten partial copies of line drawings embedded in complex backgrounds. A detecting method using SIFT [3], which is the same as the proposed method except for the feature detector and descriptor, was used for comparison. For the method with SIFT, the parameter T was set to 0.6 for obtaining the best performance. Other parameters were not changed.

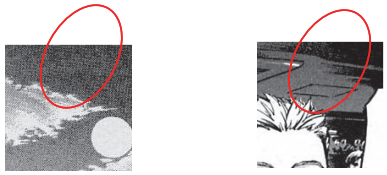
We attached the printed and handwritten partial copies on complex backgrounds as our query images. One query image contained one partial copy. The background images were randomly chosen from comic images which are not included in our database. We cropped their parts with various sizes as backgrounds. The size of a background is represented as kx if its size is k times larger than the partial copy embedded in it. We employed different backgrounds for different queries.

The results of experiments are shown in Figs. 6 and 7 with different sizes of backgrounds. Each graph shows the cumulative classification rate up to 5 retrieved images, where the horizontal axis represents the ranks.

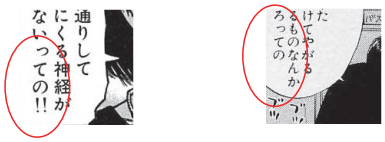
In the case of printed copies embedded in complex backgrounds, both the proposed method and the method with SIFT achieved high detection rates. However, for the detection of handwritten copies, the method with SIFT lost its effectiveness. On the other hand, the proposed method was successful to keep the detection rate as high as 95% without the background and 74% under the hardest circumstance with 10x background.

There are two reasons for the failure by the proposed method: (1) There are lots of similar patterns from different comic images as shown in Fig. 8. Erroneous matches from these parts affected the voting results. (2) Another reason was that magnified LFRs sometimes include line drawings from its background as shown in Fig. 9. This resulted in changing the value of feature vectors.

Since the dimension of one feature vector of the proposed method is much larger than one SIFT vector (128 dimensions), the proposed method costs more time for matching. The average matching time of the proposed method was 6013 ms / query, and the time of the method with SIFT was 425 ms / query.

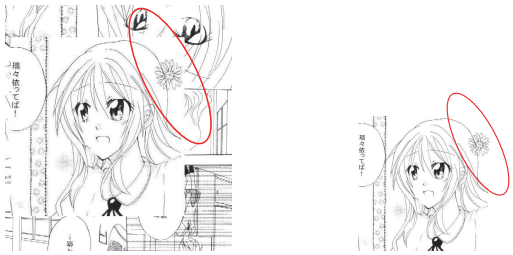


(a) LFR extracted from similar patterns.



(b) LFR extracted from same words.

Figure 8. Example of failure cases.



(a) LFR extracted from image with background.

(b) LFR extracted from image without background.

Figure 9. Example of failure cases.

4.3. Experiment 2

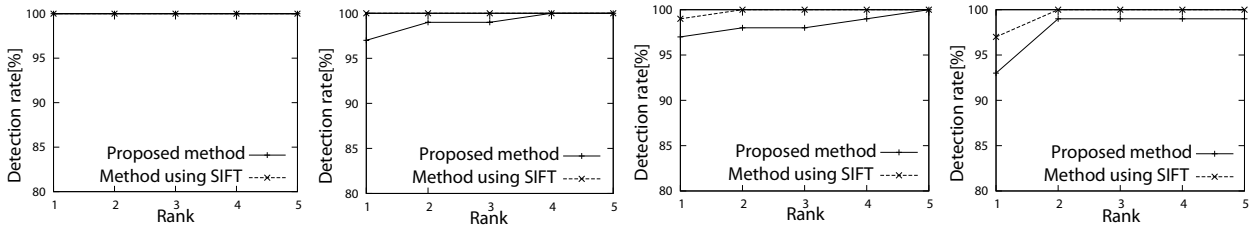
In this experiment, we explored the robustness of the proposed method for rotations and scale transformations by rotating the printed and handwritten partial copies, and scanning the partial copies with a higher resolution. We took the top 5 similar images as detection results. The results are shown in Tables 1 and 2. From the experimental results, we can see that the proposed method is robust to rotations and scale transformations in a certain range.

5. Conclusion

In this paper, we have proposed a method for detecting printed and handwritten partial copies of line drawings by

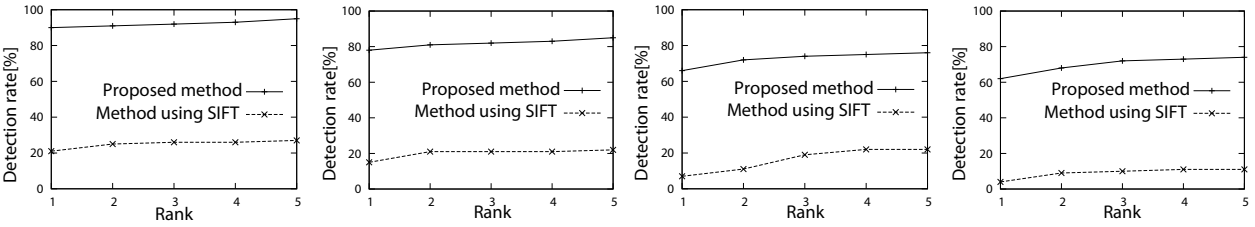
Table 1. Results under rotations.

rotate degree	0°	30°	45°
detection rate of printed partial copies	100%	99%	98%
detection rate of handwritten partial copies	94%	90%	88%



(a) Without background. (b) 2x background. (c) 4x background. (d) 10x background.

Figure 6. Results of printed copies detections.



(a) Without background. (b) 2x background. (c) 4x background. (d) 10x background.

Figure 7. Results of handwritten copies detections.

Table 2. Results under scale transformations.

scale	3/4	3/2
detection rate of printed partial copies	100%	99%
detection rate of handwritten partial copies	94%	88%

local feature matching. By using MSER as the region detector and HOG as the feature descriptor, we achieved the detection effective for both printed and handwritten partial copies from complex backgrounds. From the experimental results, we have obtained: (1) the method with SIFT achieves high detection rates for printed line drawings, but not for handwritten ones, (2) for printed line drawings, the proposed method obtains almost the same results as the method using SIFT, (3) the proposed method preforms much better on handwritten line drawings, (4) it is also robust to rotations and scale transformations in a certain range. Future work includes the improvement of the efficiency of the proposed method.

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