Colour laser printer identification using halftone texture fingerprint

Do-Guk Kim and Heung-Kyoo Lee

Numerous forgeries are made by precise and fast colour laser printers, and they have the ability to cause severe harm to society. To prevent such forgeries, printer identification can be employed as a countermeasure. A new method is presented to identify colour laser printers using halftone texture fingerprints. The method uses images photographed without an additional close-up lens as input images, and halftone texture fingerprints are extracted in the curvelet transform domain. The extracted halftone texture fingerprint is used in correlation-based detection, and the colour laser printer of the most similar known halftone texture fingerprint is determined as the source colour laser printer. Experiments are performed on five colour laser printers and the performance is compared with existing methods. Experimental results show that the method overcomes the limitations of existing methods.

Introduction: Colour laser printers are so precise and fast that forgeries using colour laser printers now have the ability to cause severe harm to society. Source colour laser printer identification is one of the digital forensics techniques that can be employed as a countermeasure to such forgeries. Researchers have introduced several methods that can be used to identify the source colour laser printer. Choi et al. [1] suggested an identification method using noise features extracted from the HH band of the wavelet domain. Ryu et al. [2] analysed the halftone texture of colour laser printed images and presented a method using halftone printing angle histogram features. Tsai et al. [3] introduced a method that uses noise features extracted from the HL, LH and HH bands of the wavelet domain. They expanded their work as a hybrid method using both noise features and grey-level co-occurrence matrix features [4]. Kim and Lee [5] presented a method using halftone texture features extracted from photographed halftone images. These listed identification techniques except Kim’s method use scanned images to identify the source colour laser printer. However, scanners are not portable devices in most cases. On the other hand, photographic devices, such as smartphones and tablets, are portable and widespread. This fact suggests that future source printer identification techniques should be able to analyse photographed images of printed material to prevent forgery effectively. Kim’s method can identify a source colour laser printer with photographed images; however, it uses close-up photographed images, which require an additional close-up lens to produce useful photographic images [5]. In this Letter, we suggest a source colour laser printer identification method that uses halftone texture fingerprints extracted from photographed images of the printed material. The proposed method uses photographed images that do not require an additional close-up lens. The input images are analysed in the discrete curvelet transform domain, and a halftone texture fingerprint is extracted. The extracted halftone texture fingerprint is compared with the halftone texture fingerprints of candidate source colour laser printers. Among the candidate source colour laser printers, the printer that has the fingerprint most similar to the extracted fingerprint is selected as the source colour laser printer of the input image. Comparative experiments with Kim’s method [5] and Tsai’s method [3] were conducted, and results show that the proposed method has a better performance than existing methods.

Printer identification method: The overall procedure of the proposed method is shown in Fig. 1. The method can be divided into two main procedures: halftone texture fingerprint extraction and correlation-based detection. In the halftone texture fingerprint extraction process, the halftone texture fingerprint of the printed material image is extracted in the discrete curvelet transform domain. The curvelet transform is a multiscale decomposition that is developed to overcome the limitations of the wavelet transform [6]. Since the wavelet transform has three directional components (horizontal, vertical, diagonal), it has limitations when representing geometrical information, such as textures and edges. Curvelet bases are multiscale and multidirectional; therefore, the curvelet transform can represent geometrical information more precisely than the wavelet transform. A frequency tiling example of curvelet transform with 6-scale decomposition in the frequency domain is shown in Fig. 2a. \( s_i \) means the ith scale of the curvelet domain, and each block represents a subband of the corresponding scale in Fig. 2a.

In the curvelet transform domain, the level of detail increases as the number of scales increases.

Fig. 1 Overall procedure of colour laser printer identification

Fig. 2 Curvelet tiling and decomposed images

(a) Curvelet tiling b Scales 1 and 2 c Scale 3 d Scale 4 e Scale 5 f Scale 6

Halftone texture can be analysed effectively and precisely in the curvelet transform domain. Frequency scale decomposed halftone images are shown in Figs. 2b–f. Each of the images in Figs. 2b–f represents an image decomposed with a specific scale of curvelet transform. Halftone texture is composed of specific dominant frequency components since it is represented as a periodic lattice. Therefore, the halftone texture can be represented with a specific curvelet transform scale. In our observation, halftone textures can be represented with the fifth scale of the curvelet transform domain as shown in Fig. 2e; the photographing distance was 9.5 cm; the original image size was 2322 × 4128 and a 512 × 512 cropped image was used for the analysis. In the fourth scale image, the halftone pattern can be discovered, but it is distorted by other frequency components of the cover image. Therefore, we extracted the halftone texture template from the fifth scale of the curvelet transform domain.

The halftone texture fingerprint extraction starts by converting an RGB image to a CMY image. Each CMY colour channel image is then analysed in the discrete curvelet transform domain. The fifth scale subbands of the curvelet transform are extracted and each subband is sorted in the descending order of its mean of the absolute coefficient value. Curvelet coefficients in the subband, of which the mean of the absolute coefficient values is higher than 70% of the maximum of the mean values of all subbands in the corresponding scale, stay at their original value. Otherwise, the coefficients are set as zero value. Curvelet coefficients in the subbands of other scales are also set as zero value. A halftone texture template is obtained by performing an inverse curvelet transform of the changed values. The halftone texture template is normalised to have a minimum pixel value of zero and a maximum pixel value of one. In this way, the halftone texture templates of each CMY colour channel are obtained.

The printing angles of each CMY toner in a colour laser printer are different from each other; therefore, the halftone texture templates of each CMY colour channel are quite different in the ideal case. However, observation showed that the halftone pattern of the dominant colour channel also appears in other colour channel templates. To avoid
misclassification caused by mixed halftone texture, only the halftone texture template of the most dominant colour channel was used to extract the fingerprint. In this process, the mean pixel value of each halftone texture template is calculated and the colour channel that has the largest mean pixel value is selected as the fingerprint extraction target.

The halftone texture template contains a halftone texture fingerprint; however, it is hard to use it directly for identification since it may have many empty regions and the size of the template is large. To improve identification accuracy and processing speed, a small-sized halftone texture fingerprint that is full of the halftone pattern is used for identification. In the proposed method, a 128 × 128-sized halftone texture fingerprint was extracted from the 512 × 512 halftone texture template. Among all the 128 × 128-sized blocks in the halftone texture templates that were overlapped as half of their size, the block that had the largest mean pixel value was extracted as the halftone texture fingerprint of the input image. Fig. 3 shows examples of halftone texture fingerprints.

![Halftone fingerprint examples](image)

**Fig. 3** Halftone fingerprint examples

After the fingerprint extraction process, the source colour laser printer is identified in the correlation-based detection process. In the correlation-based detection process, similarity measures between the extracted halftone texture fingerprint and known fingerprints are calculated:

$$\text{sim}(f_c, f_k) = \max(f_c \star f_k)$$

(1)

where $f_c$ means the extracted halftone texture fingerprint; $f_k$ means the known fingerprint and $\star$ means cross correlation. Among the known colour laser printers, the printer that has the fingerprint with the largest similarity measure is selected as the source colour laser printer.

**Experimental results:** Five colour laser printers were used for the comparison experiment to verify the performance of the proposed method; a Xerox 700 Digital Colour Press (X1), Xerox Docu Centre C6500 (X2), Xerox Docu Centre C450 (X3), Konica Minolta BizhubPress C8000 (K1) and Konica Minolta Bizhub Press C280 (K2). The proposed method, Kim’s method [5] and Tsai’s method [3] were used in the experiment to compare each performance. As Tsai’s hybrid method [4] uses both printed texts and printed images, it was not applied in the experiment. 768 cropped images of 512 × 512 size from each colour laser printer were used for the experiment. Half of them were used for training or known fingerprint data, the other half of the images were used for the identification test. The size of the original images was 2322 × 4128, and the images were photographed using a Samsung Galaxy Note 3 smartphone. The photographing distance was fixed as 9.5 cm, and the photographing angle was kept equal in all photographed images.

The printer identification results are shown in Fig. 4 and Table 1. The average accuracy of the proposed method was 86.14%, which is the highest accuracy among the three tested methods. Kim’s method showed an accuracy similar to the proposed method; however, it has a limitation in that an additional close-up lens was essential when photographing the printed material. The average accuracy of Tsai’s method was 48.07%, and it was hard to identify each source printer. Since Tsai’s method uses scanned images to identify the source colour laser printer, the result shows that there is a significant difference between methods using scanned images and photographed images. The experimental results show that the proposed method has a better performance than existing methods.

**Table 1: Printer identification results**

<table>
<thead>
<tr>
<th>Method</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>K1</th>
<th>K2</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed</td>
<td>86.68</td>
<td>75.00</td>
<td>90.10</td>
<td>84.11</td>
<td>95.83</td>
<td>86.14</td>
</tr>
<tr>
<td>Kim’s</td>
<td>82.35</td>
<td>78.99</td>
<td>97.48</td>
<td>87.39</td>
<td>75.63</td>
<td>84.37</td>
</tr>
<tr>
<td>Tsai’s</td>
<td>49.74</td>
<td>39.84</td>
<td>12.81</td>
<td>54.43</td>
<td>63.54</td>
<td>48.07</td>
</tr>
</tbody>
</table>

**Conclusion:** A colour laser printer identification method using a halftone texture fingerprint is proposed. In the proposed method, halftone texture fingerprints are extracted in the curvelet transform domain. The selected halftone texture fingerprint is used in correlation-based detection, and the colour laser printer of the most similar known halftone texture fingerprint is determined as the source colour laser printer. Experimental results showed that the proposed method had overcome the limitations of existing methods.

In future work, we will concentrate on improving the detail of the halftone texture fingerprint to enhance identification accuracy. Misclassifications mainly occurred when two printers have the same printing angle in a specific colour channel. This can be solved by using a more detailed halftone texture fingerprint. The proposed method requires a fixed photographing distance and angle, and this limitation needs to be solved before applying the method to real forensic applications. Therefore, future work will seek to acquire robustness after enhancing the identification accuracy.

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**References**


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**Fig. 4** Graph showing printer identification results