Extrinsic Signature Embedding in Text Document Using Exposure Modulation for Information Hiding and Secure Printing in Electrophotography

Pei-Ju Chiang[2], Aravind K. Mikkilineni[1], Osman Arslan[1], Roy Moshe Kumontoy[1],George T.-C. Chiu[2], Edward J. Delp[1], and Jan P. Allebach[1]

[1]School of Electrical and Computer Engineering
[2]School of Mechanical Engineering
Purdue University
West Lafayette, Indiana

Abstract

Printer identification based on a printed document can provide forensic information to protect copyright and verify authenticity. In addition to intrinsic features (intrinsic signatures) of the printer, modulating the printing process to embed specific signature (extrinsic signatures) will further extend the encoding capacity. Some features generated by modulating EP process such like raggedness of the edge in the text, can be designed and utilized to help develop the extrinsic signature. By increasing the level of modulation, which increase reliability of detection and thus capacity, we can drive the extrinsic signature to a point without perceptual degradation of the image quality. In this paper, we will investigate embedding extrinsic signature in text documents using laser intensity as a signal modulation source and develop extrinsic signatures using both frequency as well as amplitude modulation. Preliminary experimental results showed that it is feasible to embed detectable extrinsic signatures in text characters without degrading perceptual text quality.

Introduction

Banding is one of the image artifacts for electrophotographic (EP) printers. Due to its origin within the EP process, it can also be viewed as an intrinsic signature[1,2,3,4] of the specific printer. Modulating the EP process to generate banding signals that are below the human visual threshold but can be detected by effective detection approach can further extend the signature capacity. In our previous work[5], we have reported techniques that modulate the exposure of the EP process through laser intensity modulation and exploit the reduced contrast sensitivity of the human visual system at higher spatial frequencies. Unperceivable banding signatures of different frequencies and amplitudes can be embedded into an image and reliably detected.

Given the amount of text documents involved in forensic analysis, it is desirable to expand the ability to embed robust extrinsic signatures in text documents with high technical barrier of entry. The absence of large mid-tone areas makes it difficult to capture suitable signals for banding detection for text documents. Other text features such like raggedness can to be utilized to develop other types of extrinsic signatures. In this paper, we will show that by modulating the laser exposure of the EP process and exploiting the features of text, extrinsic signature of different frequencies and amplitudes can be embedded into text and reliably detected without perceptual degradation of printing quality. A HP color laser jet 4500 is used as the experimental platform for this study.

In the following sections of the paper, the method for embedding extrinsic signatures into text documents without degrading the perceptual image quality is discussed and corresponding experimental results are also provided. The summary and conclusion are given in the last section.

Method for Embedding Extrinsic Signature

Unlike halftoned images, majority of the texts are composed of individual characters with white space separating lines of texts. If laser exposure modulation can be extended to each line of characters, as shown in Fig. 1, and reliably detected, it will significantly improve the encoding capacity. As with embedding extrinsic signature in halftoned images, minimal visual impact and robust detection are the key issues for embedding extrinsic signatures in text documents.

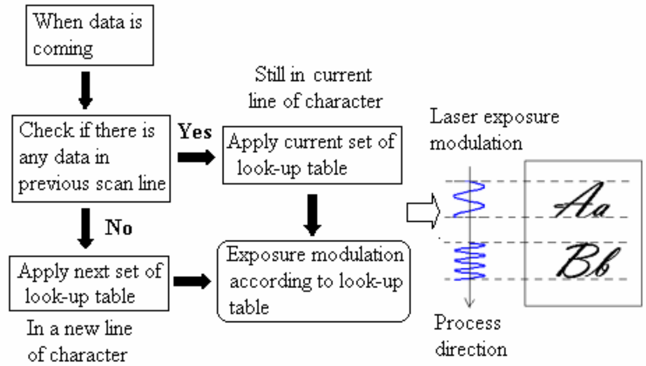

Figure 1. Embedding extrinsic signature in text

A. The Effects of Modulating Laser Intensity

Figure 2(a) shows the effect of modulating laser intensity in different types of images. The first line is printed without any modulation while the second and third lines are modulated with banding frequencies of 20 cycles per inch and 40 cycles per inch, respectively. If the modulation intensity is strong, the banding will be significant in halftoned grey scaled images shown in the right hand side of Figure 2(a). However, for characters, because of the absence of mid-tone area, the ability to detect the embedded signals is limited. However, the negative visual impact of ragged edges on text characters due to high modulation intensity is evident. Figure 2(b) shows the magnified letter I in the third line of Figure 2(a). Similar to embedding extrinsic signatures in halftoned images, the edge raggedness is a possible signature but the trade off between signature detection and image quality is the main issue that needs to be factored into the embedding strategy.

(a) (b)

Figure 2. (a) Demonstration of exposure modulation in different images. (b) Magnified letter I in the third row of (a)

B. Image Quality – Raggedness

Image quality of modulated text document will be evaluated according to ISO-13660[6]. The standard defines the edge contour of a line to be 60% transition from substrate reflectance factor to the colorant reflectance factor, as given in the following equation:

$$R_{60} = R_{\max} - 60\%(R_{\max} - R_{\min}) \tag{1}$$

where R_{max} is the maximum reflectance of the substrate and R_{min} is the minimum reflectance of the colorant. The ideal straight line is fitted in a least-squares sense to the R_{60} boundaries of the printed line. The raggedness is defined as the geometric distortion of an edge from ideal, calculated as the standard deviation of the residuals of the actual R_{60} contour to the fitted line.

In this study, a calibrated flatbed scanner is used to be an acquisition device. The scanning resolution is 600 dpi and the length of the line segment sampled for raggedness measurement is 2.54 mm (60 samples). The mean raggedness of the text edge without modulation is 8.85 µm. This will be the baseline value used to compare with the exposure modulated text characters.

C. Mapping between Laser Modulation and Raggedness

To modulate laser intensity along the process, y, direction, the reference voltage input V_{ref} to the laser power control circuit is adjusted with the following signal:

$$V_{ref} = V_0 + \frac{\Delta V}{2}\sin(2\pi f_0 y) \tag{2}$$

where V_0 is the nominal reference voltage for the laser power, f_0 is the spatial embedding frequency, and ΔV is the peak to peak amplitude of the adjustment to reference voltage that will result in variation of dot size. As the exposure modulation changes the dot size, the raggedness will also change with the intensity modulation.

To obtain the mapping between laser intensity modulation ΔV and the resulting raggedness, the test page composed of 8 letter I's with 120 pt Arial font in different rows is designed and printed with various different modulation frequencies in the 20-160 cycles per inch range with 20 cycles per inch increments. Each test page is printed with one specific intensity modulation ΔV ranged from 0.2 to 1.0 volts. Then according to the definition of raggedness defined in Eq. (1), the relationship between laser modulation and raggedness is obtained as shown in Figure 3. The dashed horizontal line in Figure 3 is the raggedness of the un-modulated text. In order to embed extrinsic signals into text documents with inherited or even better printing quality, proper intensity ΔV and spatial frequency f_0 modulations have to be selected so that the resulting raggedness is under the mean raggedness value of the text edge without any modulation. From Figure 3, the data suggests that a modulation amplitude of 0.2 volts has the largest applicable frequency range. In addition, the extrinsic signature can be a combination of frequency and amplitude modulation signals.

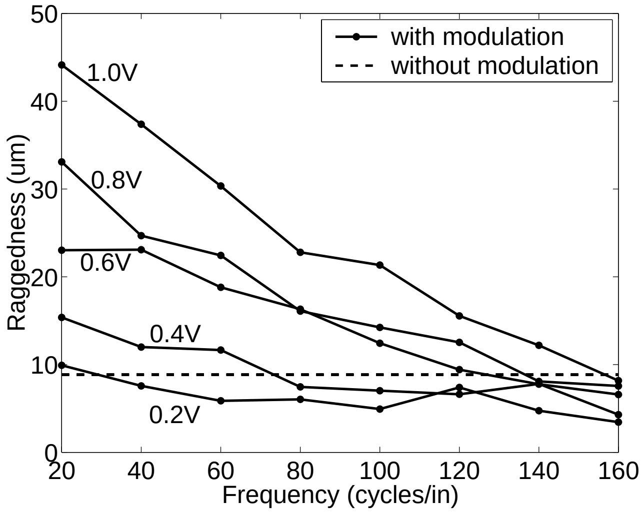

Figure 3. Relationship between exposure modulation with amplitude in 0.2~1.0 volts range and spatial frequency

To make use of frequency modulation, one also needs to notice that the frequency is lower bounded by the size of the text, i.e. the length of the sample signal during detection. For example, a 12 pt sized character sampled at 600 dpi will have at most a data length of 100 samples in the process direction. The signature frequency is also upper bounded by the combined modulation transfer function[7] (MTF) of the printer and the scanner. To further increase the capacity, we can exploit the independent lines of text. Each row of text can be embedded with a number of different FM and AM signals. This essentially becomes a coding exercise where the document content can also be utilized in the coding algorithm. At this point, we are not able to separate out different lines in a multiple column formatted document.

Experimental Results

To demonstrate embedding extrinsic signatures into text document, three lines of text with 14 pt Arial font is used as a test page. We apply frequency modulations of 60 cycles per inch and 80 cycles per inch with peak-to-peak amplitude of 0.2 volt on the first and the third row, respectively. The second row of text is un-modulated. Figure 4(a) shows magnified printout without any modulation and Figure 4(b) shows the one with modulation. Both test pages are scanned with an off-the-shelf 600 dpi flatbed scanner. It is clear that there is no visible degradation in imaging quality. To extract the embedded signature, the edge raggedness R_{60} for the left edge of the letter I from each row are calculated based on Eq. (1). Spectral analysis of the edge R_{60} values is then performed. With a 600 dpi scan, a data length of 80 samples in the process direction is extracted from a 14 pt text. Zeros are padded to the end of the data to provide more frequency samples. Figures 5-7 show the spectrum of the edge R_{60} of the letter I in each row of the text shown in Figure 4(b). It is evident of the frequency peak at 60 cycles per inch in Figure 5 (the first row) and at 80 cycles per inch in Figure 7 (the third row). Note since both amplitude of the modulation is 0.2 volts, the magnitude of the peaks are similar. To further investigate the resolution of the AM capability, we need factor into the effects of the MTFs of the printer and the scanner, respectively. This example demonstrated that by modulating the laser intensity, i.e. the exposure of the EP process and exploiting the features generated by modulating EP process in text, extrinsic signature can be embedded into text without degrading the perceived text quality compared with the un-modulated text.

(a) (b)

Figure 4(a) the printout without any modulation. (b)The printout with modulation

Conclusion

We have demonstrated the feasibility to embed extrinsic signature into text document by modulating the laser intensity and the subsequent exposure characteristics in an EP process. The feature generated by modulating EP process, and the modulation thresholds for embedding extrinsic signatures without image quality degradation are presented. Frequency analysis is used to detect the embedding signatures. Due to the font size limitation, signal length is a limiting factor for spectrum type detection approach. Alternative detection algorithms[8,9] need to be investigated to improve the detection of extrinsic signature embedding in text documents and further increase the achievable capacity.

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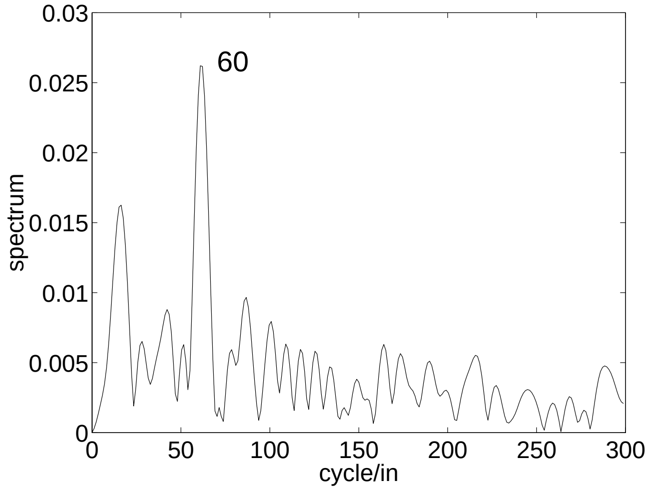

Figure 5. R_{60} spectrum of the letter I in the first row

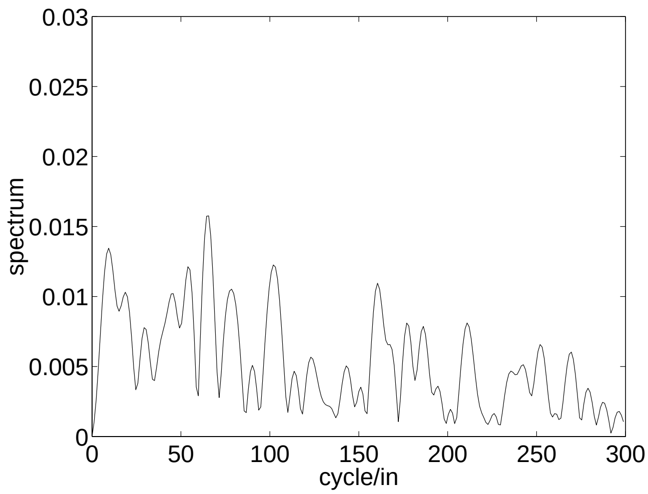

Figure 6. R_{60} spectrum of the letter I in the second row

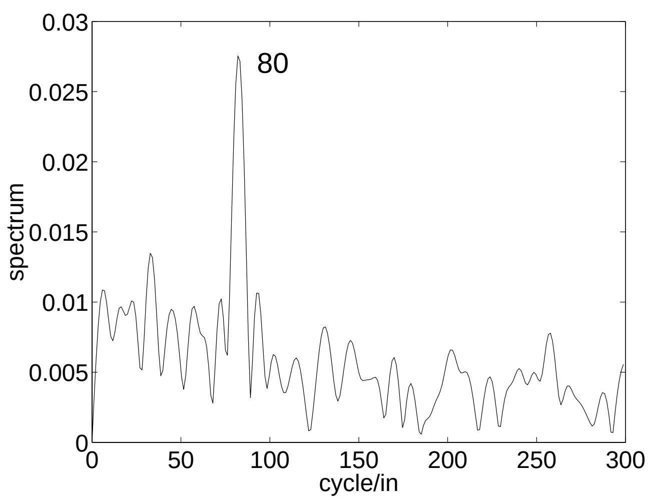

Figure 7. R_{60} spectrum of the letter I in the third row

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Author Biography

Pei-Ju Chiang received her B.S. degree in Mechanical and Marine Engineering from the National Taiwan Ocean University, in 1999 and a M.S. degree in Mechanical Engineering from the National Central University in 2001. She is currently pursuing her Ph.D. degree in the School of Mechanical Engineering at Purdue University. Her research interests are document security, modeling and analysis of digital printing and imaging processes.