SECURITY MARKS WITH FLUORESCENT TONERS IN ELECTROGRAPHIC PRINTING

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Abstract
A method for marking electrographic prints with fluorescent toner is introduced. This method allows embedding hidden marks into prints by adding fluorescent toner into image edges without halftoning the fluorescent ink channel. An analysis of edge detection algorithms for creating fluorescent ink channel is conducted. Visibility of hidden marks was tested with expert evaluation method. Capability of generating unique hidden marks for each image in a print run is shown.
Key words: *fluorescent toner, hidden mark, electrographic prints, edge detection, Canny algorithm*

Introduction

With electrographic printing being used for a wide array of printed media there are opportunities for creating additional properties in a print run without a severe increase in cost. In particularly high demand is the ability to mark prints without altering the design while also being able to identify a product sample and confirm its authenticity.

It is proposed to use additional colored fluorescent toners for this purpose. They are used in electrographic printing to widen the color gamut and make the product more attractive. In contrast to clear fluorescent inks which are widely used in security printing [7], these toners are daylight visible and their color is close to one of the CMYK inks [4].

A method is proposed for creating security marks integrated into a product's design. Moreover, these security marks will be formed based on the information contained in the image, specifically – the edges (or contours) of the image. Methods exist for creating additional channels in the image to store information about its edges. This information is then overprinted on the image to increase the visual sharpness on the edges [6]. In the proposed method, a security mark is formed in the additional fluorescent channel that replaces part of the image in the corresponding CMYK ink. For convenience, the mark is to be printed without halftoning the fluorescent toner channel. Under normal viewing conditions the mark should not be visible,

a b c

Fig. 1. An example image printed with fluorescent pink (close to CMYK magenta); a — full image; b — fluorescent toner is shown in color; c — area for potential security mark show in color. Image provided by RICOH Rus, Ltd.

Presentation of research results (Analysis)

To implement the proposed method, localization of the mark is to be determined by edge detection in the channel of the original image, that corresponds to the color of the fluorescent toner.

A variety of edge detection algorithms is known. For use in the proposed method the algorithm should satisfy the following conditions:

1. Adjustable edge detection parameters for better control over the quantity and localization of the edges to help make the mark less visible. This will also make potential falsification more difficult.
2. Isotropic sensitivity to allow for effective edge detection in a variety of images.
3. Minimal false positives.

The Canny edge detector satisfies all of these conditions [1,3]. Its adjustable parameters include blur filter radius *r* (a blur filter is applied to the image as means of noise reduction) and two thresholds for the last step of the algorithm (*t1* — upper threshold; *t2* — lower threshold).

Changing the parameters of the algorithm changes the resulting edge map — specifically it changes the area taken up by the edges relative to the whole image (*Se*). It is therefore necessary to determine the threshold of *Se* that does not make the marking noticeable on the print. The recommended ratio between the thresholds is 2:1 to 3:1 [2]. Twenty images were used for analysis. Edge maps were generated with threshold ratios of 2:1, 2,5:1 and 3:1. An example of a test image and generated edge maps is shown in fig. 2.

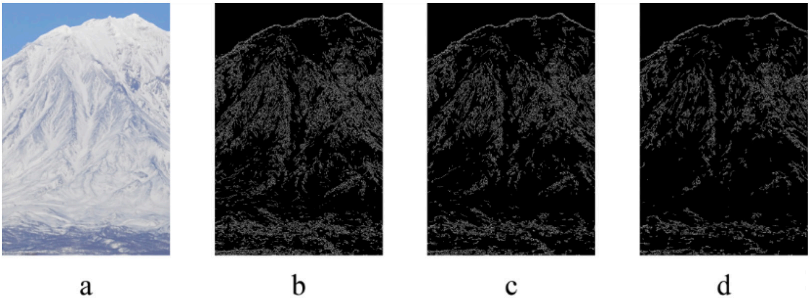

Fig. 2. An example of a test image and edge maps generated by Canny edge detector; r = 3 for all images; a – t1 = 20, t2 = 40; b – t1 = 20, t2 = 50; c – t1 = 20, t2 = 60.

The edge maps generated from the yellow image channel are used as the marking printed by the fluorescent channel (Fig. 3).

Fig. 3. A test image with the security mark; a – composite image; b – yellow channel; c – fluorescent channel; d, e, f – magnified fragment of the image.

SSIM was used as an objective measure of security mark visibility in a composite digital image. SSIM is a full-reference image quality metric. It is closely correlated to a subjective opinion based on observation [5]. In particular, images with an SSIM score above 0,9 are described by viewers as "acceptable", which can be understood as a lack of noticeable difference between the compared images. By comparing the original CMYK images to a digital image containing a simulated fluorescent marking, a linear correlation between SSIM score and the relative area taken up by the fluorescent toner is shown (fig. 4).

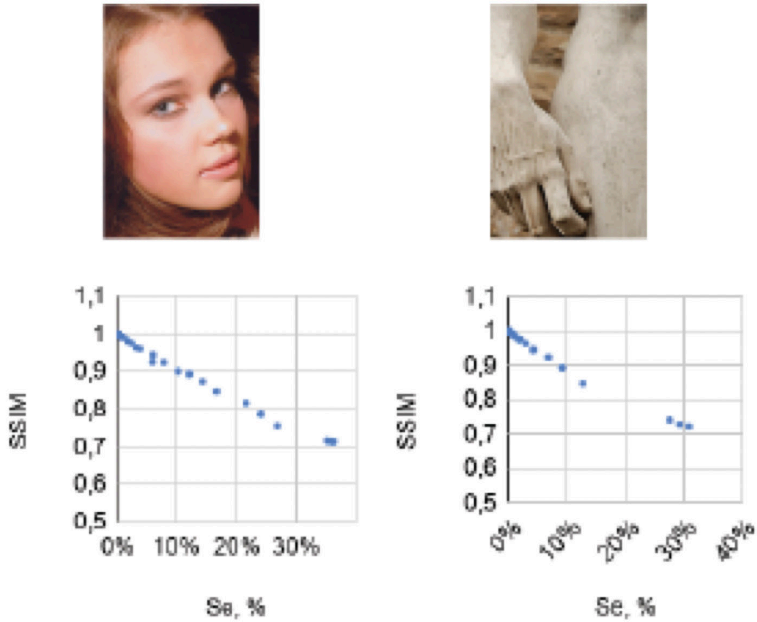

Fig. 4. Examples of test images and graphs showing the relationship between Se and SSIM score.

SSIM scores over 0.9 are reached by all of the tested images with *Se* under 10%. Consequently, Canny edge detection parameters (*r, t1, t2*) for each image are adjusted until the generated edge map satisfies this condition.

To further study the noticeability of the fluorescent marks, a visual assessment of prints produced on a Ricoh Pro C7100X press using a Neon Yellow toner was conducted. Four different images were chosen for the test (fig 5).

Two marked versions were generated from each original image — CMYK+fluorescent overprint (where the fluorescent channel was printed as is, without deleting the information from the yellow channel), and CMYK+fluorescent (where the yellow channel was "knocked out" by the fluorescent channel in the overlapping areas).

These two different methods were used to check whether it was necessary and effective to knock out the yellow ink. According to the measurements described above, edge maps were generated targeting *Se* under 10%.

Fig. 5. Test images chosen for visual assesment.

18 participants took part in the visual assessment. Each of them was firstly shown the original image, and then the two images containing the fluorescent mark. For each of the two marked images they were asked to rate the noticeability of additional structure in the image on a three-point scale, from "apparent" (0 points) to "not noticeable" (2 points). Points for each image were added up and the results are shown on the figure below (fig. 6). The original image's score is fixed to 36 (maximum possible score in the comparison).

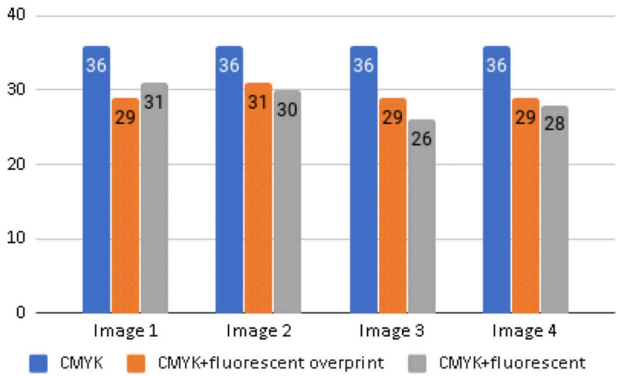

Fig. 6. Total points for each image.

As the above graph shows, for each image group the points are fairly close for the original image and both marked images, which suggests that the marks are not noticeable by an observer under normal viewing conditions.

Furthermore, images marked in different ways (overprint and knockout) are not perceived as different from each other. That suggests that the marking can be embedded in the image by overprinting.

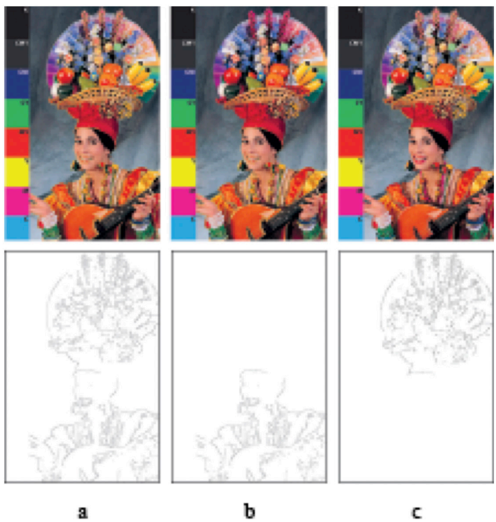

Fig. 7. Images with varying fluorescent mark localization; a - across the entire image; b - localized in the lower half of the image; c - localized in the upper half of the image

The marking can also be localized in one area instead of being embedded across the whole image (fig. 7). As it is possible to produce personalized prints in a single run, it is also possible to embed different marks in copies of the same image as an additional security feature.

Conclusions

In conclusion, a method for embedding a security mark in an electrographic print is shown. The marks are generated using an edge detection algorithm to generate an edge map from the image. It is possible to print the marks by themselves or together with design elements created using fluorescent toner. It is shown that such a marking is not noticeable under normal viewing conditions and can be embedded in the image locally, which allows for personalized prints in a print run.

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