A Novel Anti-copying Method Based on Average Grayscale Difference

Lu Zhang, De Li, and Hua Jin

Abstract—It is very common for paper documents to be copied and falsified. In view of the limitations of existing anti-copying methods, we propose a method to distinguish the photocopies and printouts based on average grayscale difference (AGD). By embedding the information layer pattern into background layer pattern, this method can distinguish the information layer pattern be recognizable in printouts, while unrecognizable in photocopies. Thus, the anti-copying effect can be achieved. In this paper, the impact of the AGD on anti-copying effect is analyzed theoretically and experimentally. Particularly, the impact of the radius and the gray value of the background circle on anti-copying performance is studied. The experimental results show the anti-copying performance of the proposed method. The method can distinguish the printouts and photocopies effectively and precisely with background circle radius *R*=8 and grayscale of 170.

Index Terms—Average gray difference, anti-copying, printouts, photocopies.

I. INTRODUCTION

Paper is an important carrier of information, and the ability to keep paper documents private is also important. In order to combat counterfeit and shoddy behavior, countries around the world developed a variety of anti-counterfeiting technologies. In general, anti-copying technology can be divided into four categories [1]: photocopier paper based on special materials, special ink printing, special printing process and superposition photocopier shading technology.

Photocopier paper based on special materials [2] is to add special substances to the paper through physical or chemical methods. When the paper is illuminated by the photocopier, the copy will appear similar blurring or discoloration, so as to achieve the purpose of anti-copying. Special ink printing [3] uses special ink to print words, which are invisible to the naked eye and can only be displayed by special instruments. Or when exposed to the light source of the photocopier, the original color will be faded to indicate that the document has been copied. Special printing process [4] refers to the use of special printing process to process text and print it on a specific carrier. For example, microfilming of documents, which uses the resolution limit of photocopiers or laser technology to reduce the size of documents to holographic

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microscopic points to prevent copying. Superposition anti-copying shading technology [5]-[7] utilizes the visual masking effect of human visual system. Visual masking [8], [9] refers to the phenomenon that the visibility of an object or image is reduced due to the presence of another object or image adjacent to it in space or time. It is a local effect peculiar to the human visual system.

The masking characteristics of human vision are influenced by texture complexity, signal frequency and background illumination. As shown in Fig. 1, two images (a) and (b), with different texture and contrast. Fig. 1 (a) is an image with low contrast with the background, Fig. 1 (b) is an image with high contrast with the background. Fig. 1 (c) is a composite of Fig. 1 (a) and Fig. 1 (b). It can be seen from Fig. 1 (c) that Fig. 1 (b) is more noticeable when the two pictures merge.
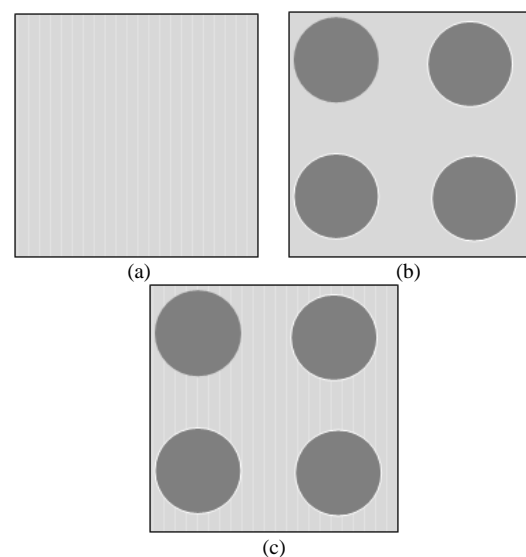

Fig. 1. Schematic diagram of visual masking effect. (a) low contrast diagram; (b) high contrast diagram; (c) synthetic diagram.

Based on this effect, anti-copying shading technology [6] achieves the purpose of hiding text and pattern information by printing the background color pattern. When reading or recognizing the contents of the paper. The hidden characters and patterns are composed of special dots, which are not easily recognized by human visual system and difficult to be found under the cover of background color patterns. However, the photocopier is sensitive to special points. Once copied, the hidden text and patterns will be clearly recognized.

The processes of printing and copying are different, and the results are also very different. Visually, the quality of the print is generally better than that of the copy. Before printing an image, the printer needs to screen the printed content. The

purpose is to convert the continuous tone image into half-tone image. Continuous tone image means that the tone of an image cannot be changed exhaustively, while half-tone image means that the change of tone in an image can be exhaustive. Then, electronic imaging technology is adopted to complete the subsequent printing processes, the specific steps are as follows:

1) Charging. Charge is to make the photosensitive drum in the dark, and apply an electric field, so that the surface of the photosensitive drum produces uniform static charge of a specific polarity.

2) Development. Development is a process of color rendering of "latent electrostatic image".

3) Transfer printing. Transfer printing is a process of transferring the toner image formed on the photographic drum to the photocopying medium.

4) Separation. Separation is a process of peeling paper from the surface of a photographic drum.

5) Photographic fixing. Photographic fixing is a process of fixing an unstable and erasable toner image on paper.

6) Cleaning. Cleaning is a process of removing toner that remain on the surface of the drum after transfer, so that it returns to its original state before entering the next printing cycle.

7) Power dissipation. Elimination of electricity is a process of eliminating residual charge on the surface of photosensitive drum, making the surface potential of photosensitive drum return to the original state.

The main difference between the photocopying process and the printing process is the exposure step. Exposure is the first process of photocopying. At this point, the exposure lamp will shine on the manuscript, reflecting light through a convex lens to the surface of the aluminum alloy drum and react with the conductive layer above. Therefore, the charge correspond to the manuscript will be eliminated. This process leads to performance loss [10], [11], and the copier cannot distinguish different adjacent grayscale levels, which will cause grayscale distortion of the copy. This is the cause of the copy quality lower than the printed copy.

In this paper, a new method for document anti-copying is proposed. It is based on the different sensitivities of printing and photocopying processes to the average grayscale difference (AGD) between the foreground and background of manuscript. That is, the anti-copying pattern, which is derived from the fusion of the background layer and the information layer, is embedded into the manuscript to act as an anti-copying sign. In normal printing, the information layer pattern is clearly displayed, and when the document is copied, the information layer pattern disappears, so as to quickly distinguish the original version from the copied document. The flow-chart of the proposed method is shown in Fig. 2. Experiments show that this method is easy to implement and has good anti-copying performance.
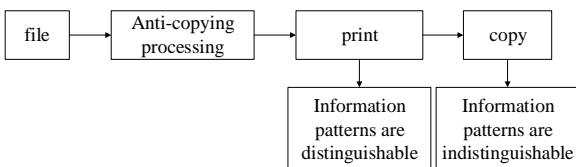

Fig. 2. The flow-chart of the proposed method.

II. Design Principle and Generation Method of Anti-copying Pattern

A. The Design Principle of Anti-copying Pattern

Suppose there are n pixels in a region X of an image. The grayscales of the n pixels are $a_1, a_2, ..., a_n$, respectively. The average grayscale, $GRAY_{avg}$, is defined as the sum of grayscale value of each pixel in region X divided by the total number of pixels, i.e.,

$$GRAY_{avg} = \frac{a_1 + a_2 +, ..., + a_n}{n} \qquad (1)$$

Further, the average gray difference between foreground and background, FBAG, is defined as

$$FBAG = \left| GRAYB_{avg} - GRAYC_{avg} \right| \qquad (2)$$

where $GRAYB_{avg}$ denotes the $GRAY_{avg}$ of background region B, $GRAYC_{avg}$ denotes the $GRAY_{avg}$ of foreground region C. The background region B and foreground region C are shown in Fig. 3.
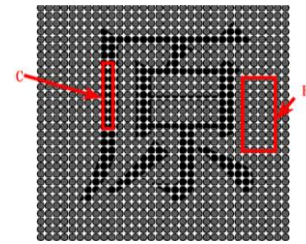

Fig. 3. Schematic diagram of *FBAG*.

The foreground area consists of circles covered by patterns, i.e., the gray scale of the pixels within the circle is 0, the average gray scale of the foreground, $GRAYF_{avg}$, is expressed by formula (3):

$$GRAYF_{avg} = \frac{255 \times (2R \times 2R - pR^2)}{2R \times 2R} = \frac{255(4-p)}{4} \qquad (3)$$

We assume that the radius of the circle $R \le t_h$, to ensure that the macro foreground region contains multiple circles; Meanwhile, influenced by discretization, if the radius of the circle is too small, the drawing of the circle has serious distortion, so the radius of the circle should meet the condition $R \ge t_l$. Generally, the background area is much larger than the foreground area, so the radius of the circle is independent of the background. In the background area, because the ratio of the area of the circle to its circumscribed square is constant, the average gray scale of the background $GRAYB_{avg}$ is expressed by formula (4):

$$GRAYB_{avg} = \frac{\pi GRAY \left(\frac{R-2}{R} \right)^2 + 255(4-\pi)}{4} \qquad (4)$$

That is, the average grayscale of the background, $GRAYB_{avg}$, is determined by the grayscale in the circle and the radius of the background circle. According to (2), the

AGD between foreground and background is expressed by formula (5):

$$FBAG = \frac{\pi GRAY \left(\frac{R-2}{R} \right)^2}{4} \qquad (5)$$

The above analysis shows that the AGD between foreground and background is determined by the grayscale and the radius of the background circle. We find that when the value of *FBAG* is in a certain range, the effect of copy prevention can be achieved

B. The Method for Generating Anti-copying Patterns

Based on the above analysis, an anti-copying pattern, which includes background layer and information layer (foreground), is designed. The background layer consists of repeating circles of the same size. The radius of the circles is R , the grayscale of each pixel within the circles is *GRAY* . The background layer pattern is shown as Fig. 4.
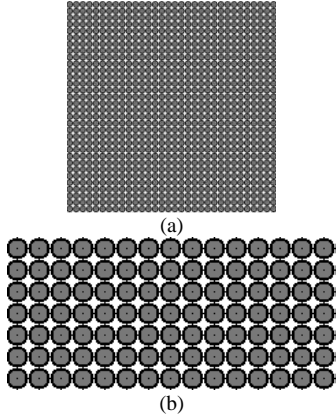

(a)

(b)

Fig. 4. The background layer pattern. (a) the overall background layer pattern. (b) zoom in on the background layer pattern.

The pattern of information layer should be a graph with special significance such as text, number, letter or logo, as shown in Fig. 5 (a). After fusion of the background layer and the foreground layer, the anti-copying pattern is shown in Fig. 5 (b). According to the masking effect of human visual system[8], because the contrast of the background layer pattern is less than that of the information layer pattern, the printing shows the characteristics of the information layer pattern, The word "原" can be clearly displayed.
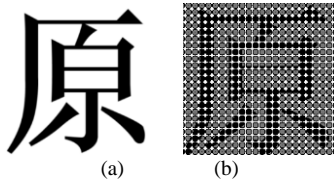

(a)   (b)

Fig. 5. Information layer pattern and its generated anti-copying pattern. (a) information layer pattern. (b) anti-copying pattern.

During the anti-copying pattern generation process, the first step is to determine the anti-copying pattern size based on the page size. Then draw the background layer image according to the pattern size. Finally, the information layer image and background layer image are merged by superposition to generate photocopy-proof image. The specific flow chart is shown in Fig. 6.
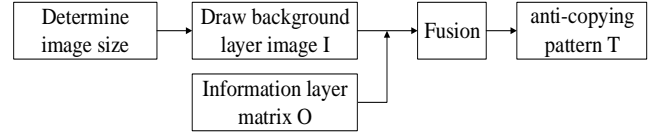

Fig. 6. Flow chart of the anti-copying pattern generation process.

Specific implementation steps are as follows:

Input: N , R , $GRAY$, t_l , t_h , where $t_l \le R \le t_h$, O

Output: T

Step 1: initialize the background layer matrix $I = \mathbf{0}_{N \times N}$;

Step 2: draw a background layer pattern on the background layer matrix. The background pattern is composed of multiple circles;

(2a) determine the coordinate (i, j) of the center of the circle, where i and j denote the x-coordinate and y-coordinate respectively. The i and j are initialized as $i = R+1$, $j = R+1$;

(2b) Set the grayscale value of the pixel in the circle;

(2b.1) $I_{tmp} = I(i-R:i+R, j-R:j+R)$, where I_{tmp} represents the temporary memory space; $I(i-R:i+R, j-R:j+R)$ denotes the matrix consists of the elements between $(i-R, i+R)$ and $(i-R, i+R)$ in I , initialize intermediate variable $x=1$, $y=1$

(2b.2) IF $(R-2)^2 < \left[x-(R+1) \right]^2 + \left[y-(R+1) \right]^2 < R^2$

$I_{tmp}(x, y) = 0$;

ELSE IF $\left[x-(R+1) \right]^2 + \left[y-(R+1) \right]^2 < (R-2)^2$

$I_{tmp}(x, y) = GRAY$;

ELSE

$I_{tmp}(x, y) = 255$;

END

where $I_{tmp}(x, y)$ denotes the matrix element with coordinate (x, y) ;

(2b.3) $x = x+1$;

    IF $x \le 2R+1$

        go to (2b.2);

    ELSE

        $x = 1$;

        go to (2b.4);

    END

(2b.4) $y = y+1$;

    IF $y \le 2R+1$

        go to (2b.2);

    ELSE

        $I(i-R:i+R, j-R:j+R) = I_{tmp}$;

        go to (2b.4);

        go to (2c);

    END

(2c) $i = i+2R$;

    IF $i \le N-R$

        go to (2b);

    ELSE

        $i = R+1$;

go to (2d);
　　END
　(2d)　$j = j + 2R$;
　　　IF $j \leq N - R$
　　　　go to (2b);
　　　ELSE
　　　　go to Step 3;
　　END

Step 3: load the information layer matrix O; matrix O has the same size with I; The matrix O and matrix I are fused to get the fusion matrix T, the size of T is the same as I, the flowchart is shown in Fig. 7;

　(3a) initialize $T = \mathbf{0}_{N \times N}$, $m = 1$, $n = 1$
　(3b) IF $O(m,n) == 0$ AND $I(m,n) \neq 255$

　　　$T(m,n) = O(m,n)$

　　　ELSE
　　　$T(m,n) = I(m,n)$

END
　(3c)　$m = m + 1$;
　　　IF $m \leq N$
　　　　go to (3b);
　　　ELSE
　　　　$m = 1$;
　　　　go to (3d);
　　　END
　(3d)　$n = n + 1$;
　　　IF $n \leq N$
　　　　go to (3b);
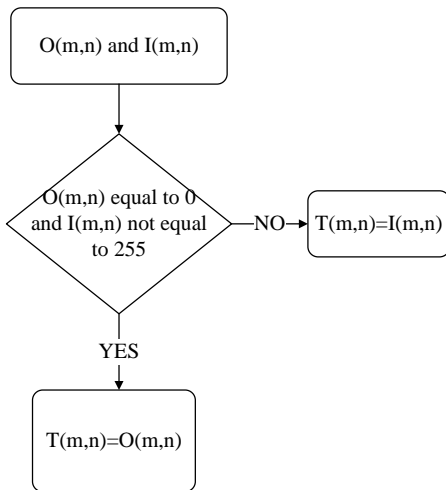　　　ELSE
　　　　output T
　　　END

Fig. 7. The flowchart of the fusion of the background layer and information layer.

III. EXPERIMENTAL RESULTS AND ANALYSIS

The performance of the proposed method is affected by the average gray difference between foreground and background. In this paper, the effect of radius and grayscale on anti-copying performance is evaluated through the following experiments.

A. Effect of Background Circle Radius on Anti-copying Performance

Set the grayscale of the pixels in the background circle unchanged, i.e., $GRAY = 170$, Change the radius of the background circle R. When the radius of the circle is 4 pixels, the resulting background pattern is no longer circular caused by discretization, so the smallest radius $t_l = 5$. To fully present the foreground image, the radius of the background circle should not be too large. Experiments show that when the radius of the background circle is 8 pixels, the foreground image can be completely presented, so $t_h = 8$.

The experimental results are shown in Table I, the second column shows the printed images with radius set as 5, 6, 7 and 8 respectively, and the third column shows the corresponding copy results. Compare the two columns of Table I, it can be seen that when the radius is 5 or 6, the foreground image is no longer visible after copying. When the radius is 7 or 8, many foreground lines no longer contain a full circle. At this point, the assumption that the macro foreground contains multiple circles is no longer strictly met. Therefore, after photocopying, the foreground text is still partially visible which means the anti-copying effect is poor.

TABLE I: THE EFFECT OF RADIUS ON ANTI - COPYING EFFECT WAS STUDIED

Radius	Print	Copy
5		
6		
7		
8		

B. The Effect of Grayscale of the Background Circle on Anti-copying Performance

In this experiment, keep the circle radius unchanged, i.e., $R = 8$. The AGD between foreground and background is changed by changing the gray value in the circle. According to human visual characteristics [9], human visual system can only distinguish about 30 levels of grayscale. Considering that the image grayscale has 256 levels, we did 32 trials with changed grayscale.

Some experimental results are shown in Table II, the left column is the printed image and the right column is the photocopied image. It can be found that when the value of grayscale is greater than or equal to 79, the foreground image can be clearly recognized in printouts. However, after photocopying, in order to effectively identify the foreground image, the grayscale should be greater than 191. Therefore,

this experiment verifies that the sensitivity of photocopier to the AGD between foreground and background is weaker than that of printer. This is to say, higher AGD between foreground and background is needed in order to achieve good photocopying performance. On the other hand, when the grayscale ranged from 79 to 175, we can achieve the effect of anti-copying.

TABLE II: THE EFFECT OF CIRCLE GRAY ON ANTI-COPYING EFFECT WAS STUDIED

grayscale	print	copy
15		
31		
47		
63		
79		
95		
111		
127		
143		
159		
175		
191		
207		
223		
239		
254		

### C. Solid Color Background Effect Comparison

To verify the performance of the method in this paper, the background is replaced with solid color, and the experimental result is shown in Table III. The printed images are shown in left column. The background grayscales of the image are 50, 60, 70, 80, 90, 100, 110 and 120 respectively, and the copy images are shown in right column. It can be seen that when the gray value of solid background is 50, the foreground pattern of the copy image can be recognized, and with the increase of the background gray values, the foreground patterns become clearer and clearer. Therefore, the anti-copying effect is difficult to be achieved by the solid color background.

TABLE III: PURE COLOR EXPERIMENT

grayscale	print	copy
50		
60		
70		
80		
90		
100		
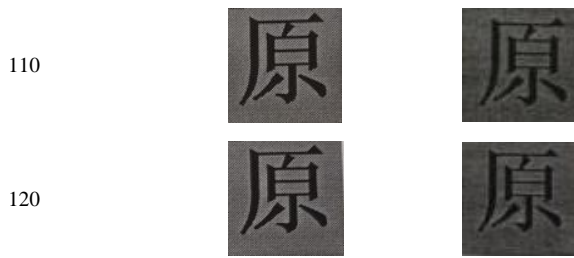
The AGD between background and foreground of images with different parameters, corresponding to designed background patterns and solid color background, respectively, are shown in Fig. 8.
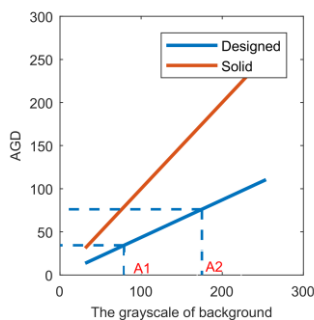

Fig. 8. Relation between average gray difference and background grayscale.

In the area 0-$A1$, the information layer pattern cannot be recognized in both printed and copied image. In the area $A1$-$A2$, the information pattern in printed image can be recognized, but the information pattern in copied image cannot be recognized. In the area $A2$-255, the information layer pattern can be recognized in both printed and copied images. Therefore, when the experimental parameters are located in the area $A1$-$A2$, the anti-copying effect can be achieved. According to the experiment, we find that $A1 = 79$, $A2 = 175$.

Fig. 9 shows the effectiveness of this method. Fig. 9 (a) shows the printed image, and Fig. 9 (b) shows the copied image. We set radius $R=7$ and $GRAY=170$ for printing. It can be seen that the method in this paper achieves a good anti-copying performance.
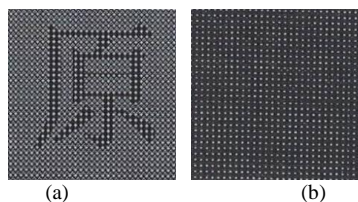

(a)   (b)

Fig. 9. Experimental rendering. (a) Print renderings. (b)Copy the renderings.

IV. CONCLUSION

In this paper, a new anti-copying method is proposed. Particularly, anti-copying patterns are added to normal documents. Anti-copying patterns are generated by merging information layer patterns with background layer patterns. The information layer pattern is made up of circles arranged in a repetitive way to cover the entire pattern area. Information layer patterns can be letters, numbers, text, or

other logo patterns. When the file is printed normally, the information layer pattern is clearly displayed, and when the document is copied, the information layer pattern disappears. Based on this, we can tell whether an image is printed or copied. This method has the following advantages:

1) The information layer pattern can be in various forms, including text, letters, numbers, or other patterns, with strong portability.

2) The anti-copying pattern can be generated and identified intuitively and quickly when copying.

The proposed method still needs improvement. For example, the information layer pattern needs to use a simple pattern. And the more complex pattern cannot be fully presented when printing. In this paper, only the circular pattern is tested as the background pattern unit, on this basis, diamond, square and other graphics can be designed as background pattern unit for testing as well.

CONFLICT OF INTEREST

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

AUTHOR CONTRIBUTIONS

Lu Zhang conducted the research and wrote the paper; De Li analyzed the data; De Li and Hua Jin revised the paper; all authors had approved the final version.

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