Digital Watermark for Printing Images

-Application to Thermal Transfer Printing Method-

Nobuki Nemoto, Takeo Miki, Takashi Yamaguchi; Power and Industrial Systems Research and Development Center, Toshiba Corporation; Kawasaki-shi, Kanagawa-ken, Japan

Abstract

We have introduced an information embedding method on a digital watermark for a printing image and applied to thermal transfer printing. In this method, printed dots are arranged in staggered array to obtain area coverage modulation in each dot in thermal transfer printing. It is possible to correctly embed sub image information in this typical dot array and to electronically restore the sub image information. We confirmed that both invisibility characteristics and restoration characteristics are quite good and the digital watermarks can be normally embedded and restored as the result from the evaluations of 100 images printed at the resolution of 400 dpi after textual sub image information was embedded.

Introduction

An identification card (ID card) is one of the most important devices for physical security systems. Recently, the spread of color printers and scanners has increased the risk of abusing ID card copies. In order to prevent abusing ID card copies, there is a technique of digital watermark for printing. Digital watermark is usually embedded in digital information but can be embedded in a printing image such as a picture of a human face with this technique.

The outline of digital watermark for printing is shown at Figure1. Four kinds of data, namely, main image, sub image, key image (1) and key image (2) are used for input data. The main image information is a normal image such as an image of human face printed on ID cards. Therefore, the main image is the subject to protect from counterfeiting. The sub image information is digital watermark and an image invisibly embedded in the main image to raise a level of security. Thus, an image having meaning such as logo marks or monochrome binary image made by replacing 0/1 bit sequence of sub information, for example, with white/black pixel, is used as sub information. The key image is later used to pick out the sub information that is digital watermark, and a monochrome binary image into which the 0/1 bit sequence of the key information is converted. A print piece is created by using four kinds of data, namely, the main image, sub image, key image (1) and key image (2), embedding digital water mark, synthesizing image as output data, and printing it with a full-color printer which has ability of high resolution printing. The printed synthetic image is that sub image is invisibly embedded in main image as digital watermark. The sub image is invisible for human eyesight, but it is saved in the synthetic image and left undeleted after printing. This point is the major difference from the existing technique of digital watermark used only under digital environment.

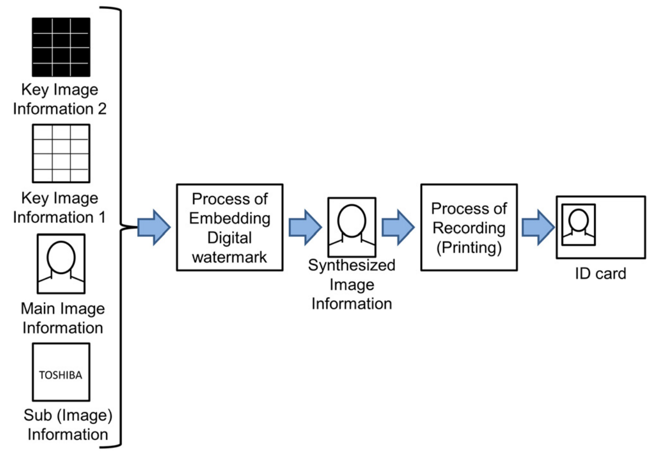

Figure 1. *Schematic illustration for the outline of digital watermark process for printing*

On the other hand, thermal transfer printing is one of the useful methods to print ID cards. However, processing the main image to remove some pixels, printed dots are arranged in staggered array to obtain area coverage modulation in each dot in thermal transfer printing. Thus, some pixels of the sub image information that is the digital watermark are absent in the printed image even when the main image and the sub image are synthesized. Therefore, we have developed a new technique to apply the digital watermark for printing by which sub image such as letters and numbers is embedded in the printed image as fine patterns of color-difference modulation to thermal transfer printing. Using this method, it is possible to correctly embed sub image information in this typical dot array and to electronically restore the sub image information. In this paper, we report on the method to apply digital watermark to thermal transfer printing and the results of evaluations about invisibility and restoration.

Principle

We conducted the color-difference modulation process using the two human visual features below to obtain a digital watermark for printing.

(1) The higher spatial frequency of an image is, the lower ability to distinguish the tone we have [1].

(2) It is more difficult for human eyesight to distinguish color-difference than luminance [1].

In addition to these human features, by using the relationship of complementary colors [2], it is possible to keep color of main image information when sub image information is superimposed on the main image information. When the printing resolution is larger than 300 pixels per inch, it becomes hard to sense the color-difference of two adjacent pixels for human eyesight. Using this characteristic, digital watermark can be embedded in printing images as invisible fine color-difference modulation. It is difficult to photocopy the printing with office automation equipment because embedded digital watermark is fine pattern.

Methods

Digital watermark embedding method [9]

In order to embed digital watermark for printing, we applied the relationship of complementary colors and information of color-difference to an image of high frequency carrier pattern. We explain the color-difference modulation process which embeds digital watermark by color difference information. Figure 2 shows the schematic illustration for the color difference modulation process. Figure 2 (a) shows a part of key information of line A-A' (8 column pixels × 1 row pixel). It shows that the white parts are white pixels and the shaded parts are black pixels. Color difference amount △CD is separated to three components as R (red), G (green) and B (blue). Each of them is named △CD-R, △CD-G and △CD-B. The color difference modulation process is executed by calculating each △CD-R, △CD-G and △CD-B according to the following equations (1) to (6). Figure 2 (b) to Figure 2 (d) show RSLT-R, RSLT-G and RSLT-B which are separated from the results of color-difference modulation. Line B-B' of Figure 2 (e) shows the result of synthesizing RGB components. When key information is a white pixel, the pixel is R-rich (red component rich) and when key information is a black pixel, the pixel is C-rich (cyan component rich).

When key information (i, j) = white pixel

$$RSLT(i,j)\text{-}R = +\Delta CD\text{-}R \quad (1)$$

$$RSLT(i,j)\text{-}G = -\Delta CD\text{-}G \quad (2)$$

$$RSLT(i,j)\text{-}B = -\Delta CD - B \quad (3)$$

When key information (i, j) = black pixel

$$RSLT(i,j)\text{-}R = -\triangle CD\text{-}R \quad (4)$$

$$RSLT(i,j)\text{-}G = +\triangle CD\text{-}G \quad (5)$$

$$RSLT(i,j)\text{-}B = +\triangle CD\text{-}B \quad (6)$$

As red color and cyan color are physical complementary colors at additive color mixing, the mixed color of both is achromatic color. Therefore, setting the pixel pitch at high resolution (approximately more than 300 pixels per inch) which is over the human sensing range, it is impossible for human eyesight to distinguish the red color from the cyan color and it is an achromatic color that human eyesight senses from the result after the color-difference modulation process. Using this characteristic, a pattern of the key image can be converted into a pattern of color-difference information and can be replaced by achromatic information to the eye.

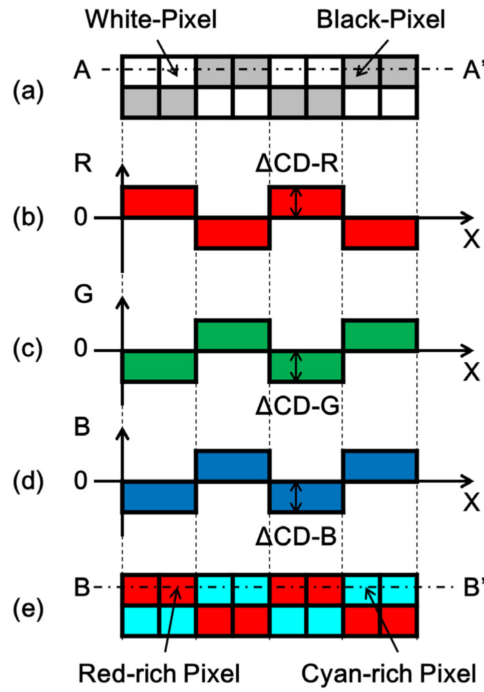

***Figure 2.** Schematic illustration for the color difference modulation process [9]*

Application to thermal transfer printing method

In thermal transfer printing, printed dots are arranged in staggered array to obtain area coverage modulation in each dot. Because of this dot array, some pixels including sub information are not printed even if the color-difference modulation process is used. As a result, sub information is not correctly recorded in a printed image. We have developed a new method of embedding sub information to embed digital watermark in this typical dot array. Figure 3 shows a schematic illustration for the outline of the process to produce an ID card which has sub information of digital watermark embedded with our method. The original point of our method is to synthesize a rotated main image, a sub image and key images.

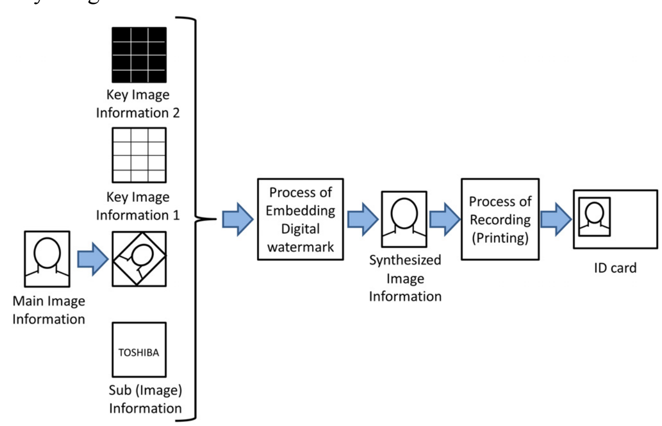

***Figure 3.** Schematic illustration for the outline of digital watermark process*

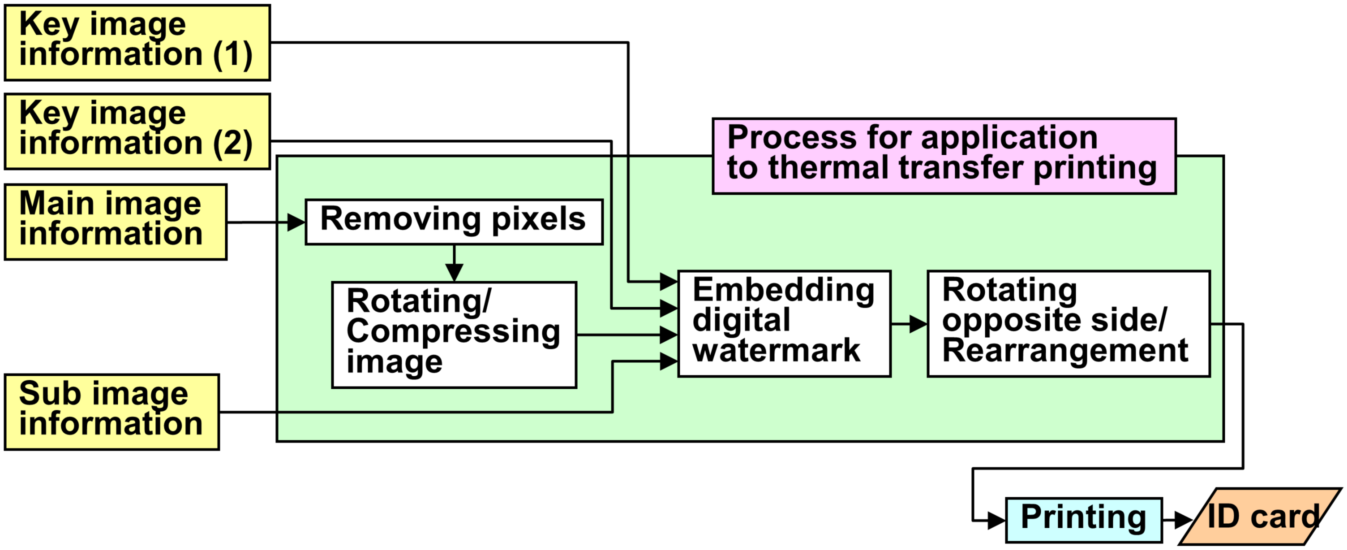

Figure 4. *Schematic illustration for the flow of the process for application to thermal transfer printing*

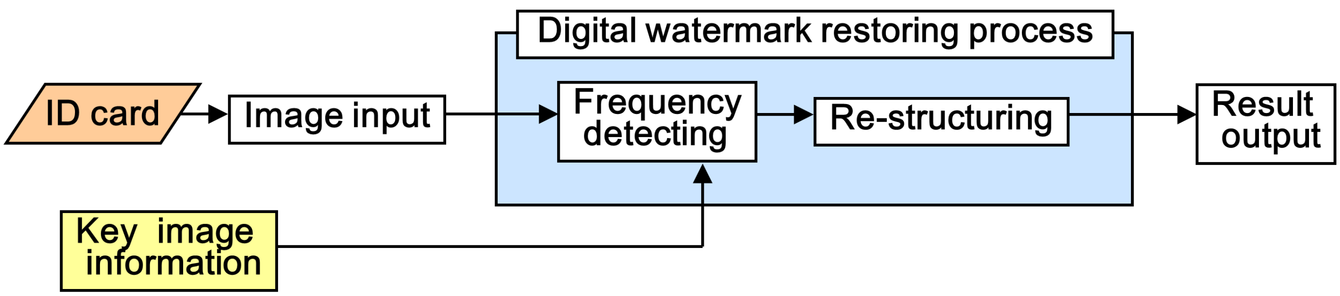

Figure 5. *Schematic illustration for the flow of digital watermark restoring process [9]*

Figure 4 shows the flow of the process for application to thermal transfer printing: rotating a main image and synthesizing it with a sub image and key images.

The first process is removing pixels process: inputting main image information and remove some pixels form the main image. The printing process in later needs this process.

The second process is rotating and compressing image process: inputting the main image processed by the first process and rotating the main image 45 degrees and compressing it as filling in the blank pixels.

The third process is embedding digital watermark process: inputting the main image processed by the second process, a sub image and key images and synthesizing them.

The fourth process is rotating the image to opposite side and rearrangement process: inputting the image synthesized by the third process and rotating it 45 degrees to the opposite side and rearrange the pixels of the compressed image as the image just before compressed.

Executing the first process to the fourth process as noted above, we embedded sub image information in a staggered array of a main image. This process enables to apply digital watermark to thermal transfer printing.

Restoring method [10]

We explain the method restoring sub image information from a printed image in which sub image information is invisibly embedded. The sub image information embedded in the main image is restored by detecting a specific spatial frequency component based on the key information used in the embedding digital watermark process and reconstructing the sub image information of the spatial frequency component. Figure 5 shows schematic illustration for the flow of process restoring a digital watermark from a printed image in which sub image information is embedded. The process of restoring a sub image from a printed image in which digital watermark is embedded includes the following three processes.

(1) Image input process
(2) Frequency detecting process
(3) Re-structuring process

In the image input process (1), scanning a printed image in which digital watermark is embedded with a scanner and inputting the scanned image information are executed. In the frequency detecting process (2), filtering color components by the frequency and picking out information of amplitude (i.e. intensity) and position are executed. In the re-structuring process, smoothing the amplitude information, selecting an optimal result among the RGB and re-structuring the modulated components that are sub image information are executed [8].

We particularly explain frequency detecting process (2) and Re-structuring process (3) which are core processes when a sub image is restored.

In frequency detecting process (2), the method for detecting a specific spatial frequency component based on the key information is to conduct following processes from (2-1) to (2-4) with a spatial frequency filter.

(2-1) Resizing key image information based on the resolutions of main image information, synthesized image information printed on a media for recording and scanned image information in the image input process
(2-2) Conducting frequency expansion by Fourier transformation
(2-3) Coordinating a passband of the filter by referring to the value of frequency expansion
(2-4) Conducting Fourier inverse transformation to coordinated value and using the result value as coefficient of spatial frequency filter

Embedded key information changes its basic frequency to the same frequency which was resized as the ratio of scanning resolution and printing resolution by the process (2-1). Therefore, the change of printing resolution and scanning resolution is calculated when the coefficient of spatial frequency filter is calculated. The process is executed in each color of R (red), G (green) and B (blue).

Re-structuring process (3) is to conduct the following processes from (3-1) to (3-3).

(3-1) Visualizing spatial frequency components detected in each three plain color unit by smoothing process
(3-2) Selecting an optimal value among the three smoothed input values based on the SN ratio of signals
(3-3) Converting the selected value into 8 bit data by normalizing the selected value as the maximum value is 255 and the minimum value is 0

Figure 6 shows schematic illustration for the smoothing process of the re-structuring process. Figure 6 (a) shows the signal of the detected frequency component. The horizontal axis is position and vertical axis is amplitude (i.e. intensity of the signal). In real process, it is not simple 2-dementional graph, but 3-dementional because it shows the relationship between the amplitude of frequency and the position of a 2-dementional image. Process of calculating absolute value and multiplying by constant and moving average process are executed as Figure 6.

Figure 7 shows schematic illustration for the normalizing process (3-3) of the re-structuring process. The result after smoothing process (3-1) and selecting process (3-2) has mixed two kinds of peak. One of them has relatively large peak (A2) and the other has relatively small peak (A1) as Figure 7 (a). Normalizing process coordinate transformation as maximum value is 255 and minimum value is 0 because 8 bit data is generally assigned for each color plain as Figure 7 (b).

Executing frequency detecting process (2) and re-structuring process (3) to input image information as noted above enable to restore the sub image information embedded as patterns of color-difference modulation.

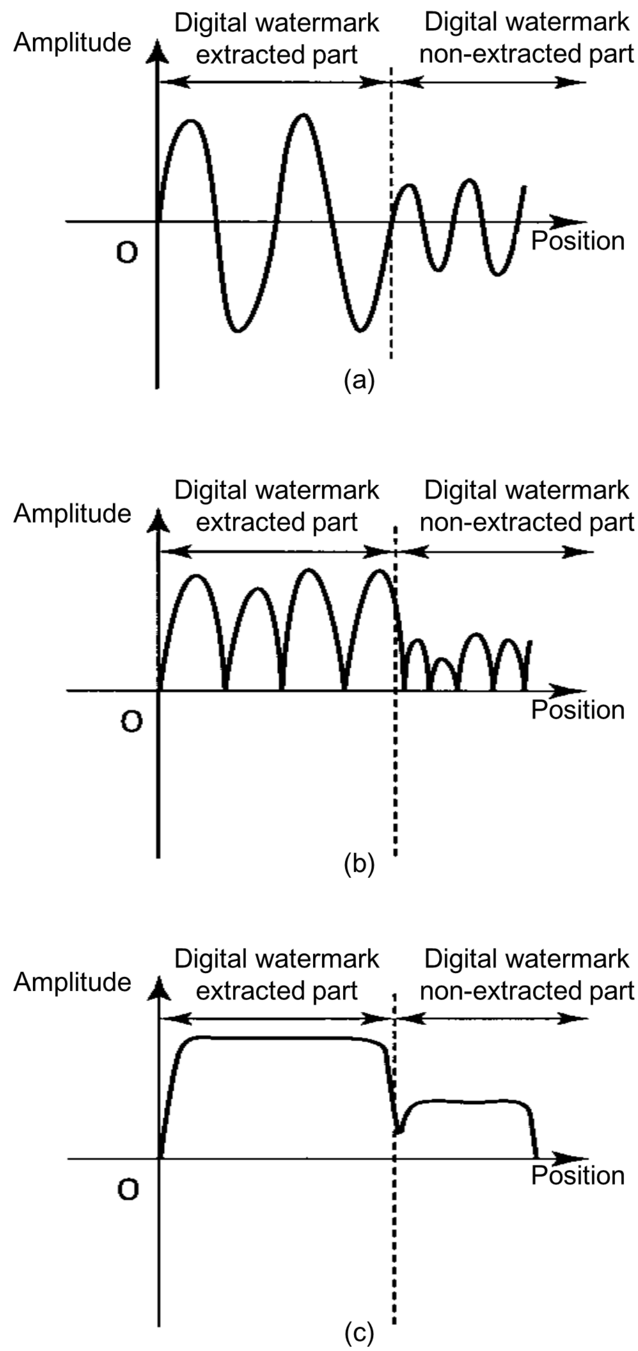

Figure 6. *Schematic illustration for the smoothing process of the re-structuring process [7] (a) Amplitude of spatial frequency, (b) Calculating absolute value and multiplying by constant, (c) Moving average process*

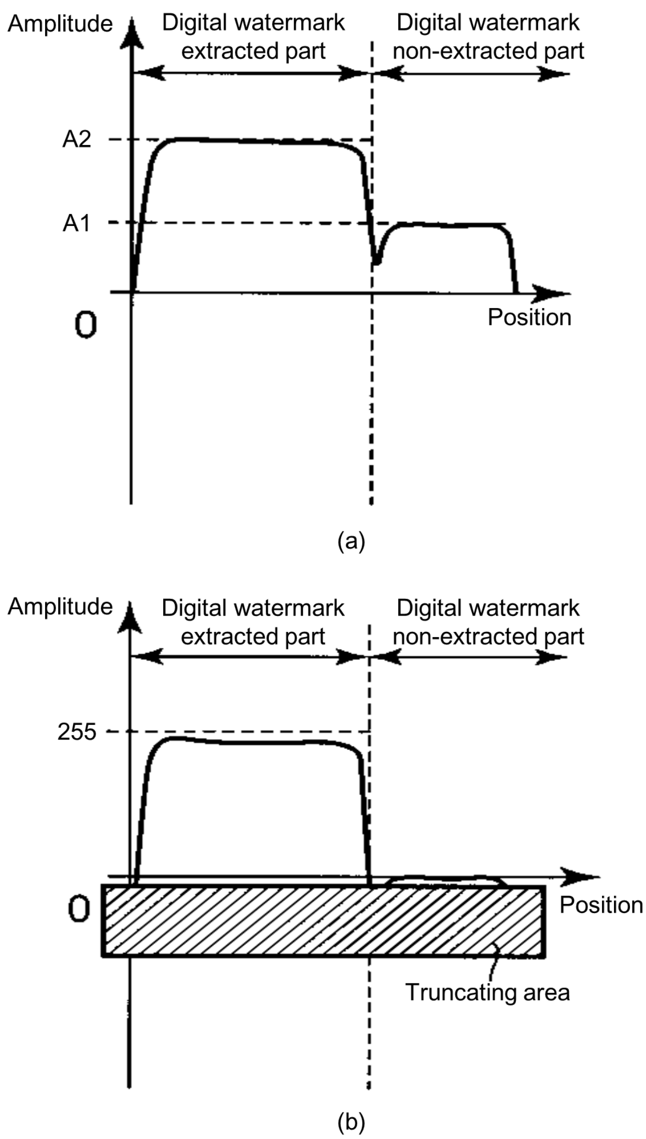

Figure 7. *Schematic illustration for the normalizing process of the re-structuring process [7] (a) Smoothed and averaged wave form, (b) Normalizing process*

Evaluations

Evaluation of invisibility

We have evaluated invisibility of the digital watermark embedded in a printed image. The invisibility evaluation was conducted by confirming if digital watermark can be seen in an image printed with a printer for the evaluations as shown in Table 1 after embedding digital watermark. The evaluation of invisibility was conducted as following (1) and (2). Table 2 shows the results of the invisibility evaluation.

(1) Evaluated images:
Face images of 100 persons in which digital watermark is embedded each
(2) Method of the evaluation:
(a) Visual observation of the printed images in which digital watermark is embedded by evaluators
(b) Basis for the evaluation:
five-grade evaluation (from 1: Excellent to 5: Poor)
(c) 9 evaluators

There was no image in which digital watermark was visibly embedded among evaluated 100 images because the mean value of five-grade evaluation (from 1: Excellent to 5: Poor) was 1.43 and there was no image whose evaluation value was more than 3.00 (average). The variation among the evaluators was low because the value of standard deviation was 0.37. Therefore, digital watermarks were invisible for the 100 images evaluated in this research.

Table 1 Specification of the printer for evaluations

Resolution (dpi)	400
Printing method	Thermal transfer
Color	CMY
Printing levels	256 levels per color (CMY)

Table 2 Results of the evaluation of invisibility

Total image count	100
Mean value	1.43
Standard deviation	0.37
Minimum value	1.00
Maximum value	2.71

Evaluation of restoration

We have also evaluated restoration of digital watermark embedded in a printed image. The restoration evaluation was conducted by confirming if digital watermark can be correctly restored from an image printed with the printer for the evaluations (Table 1) by the restoring process. The evaluation of restoration was conducted as following (1) and (2). Table 3 shows the results of the restoration evaluation.

(1) Evaluated images:
Restored images of digital watermark from the images in which digital watermark is embedded
(2) Method of the evaluation:
(a) Visual observation of the images of restored digital watermark shown on a liquid crystal display by evaluators
(b) Basis for the evaluation:
Judging success/failure by major vote for each image confirming if embedded letters in the restored image is readable
(c) 5 evaluators

Table 3 Results of the evaluation of restoration

Total image count	100
Pass count	100
Pass rate	100%

All the five evaluators judged success for all the 100 images and the ratio of success was 100%. We have confirmed that our method can restore a digital watermark.

Conclusions

We have developed the technique to embed a digital watermark applied to thermal transfer printing. Then, we confirmed that both invisibility characteristics and restoration characteristics are quite good and the digital watermarks can be normally embedded and restored as the result from the evaluations of 100 images printed at the resolution of 400 dpi after textual sub image information was embedded. This method enables that each ID card has specific information and raises level of security of ID cards.

The next goals are (1) increasing the amount of information embedded as digital watermark and (2) applying this method to machine readable code.

References

[1]Hidekazu Sekizawa et al. "Recoding deep layer information of color images", in Japanese, Proceedings of 23rd Media Computing Conference, pg.47-48 (1995)

[2]Tadashi Yamamoto et al. "Image Recoding and Reproducing Device", in Japanese, Japan Patent 3547892 (2004)

[3]Takashi Yamaguchi et al. "Picture Information Processing Method", in Japanese, Japan Patent 4015753 (2007)

[4]Takashi Yamaguchi et al. "Image Processing Method", in Japanese, Japan Patent 4167590 (2008)

[5]Shinya Tokuda et al. "Image Processing System", in Japanese, Japan Patent 4227048 (2008)

[6]Takeo Miki et al. "Image Printing Method, Image Printing Apparatus", in Japanese, Japan Patent 4327676 (2009)

[7]Takashi Yamaguchi et al. "Image Processing Method, Image Processing Apparatus", in Japanese, Japan Patent 4550749 (2010)

[8]Shinya Tokuda et al. "Image Processing Apparatus, Image Processing Method", in Japanese, Japan Patent 4746663 (2011)

[9]Takashi Yamaguchi et al. "Digital Watermark for Printing –Study of Information Embedding Method– ", in Japanese, Proceeding of the 113th Imaging Conference JAPAN 2014, pg.107-110 (2014)

[10] Nobuki Nemoto et al. "Digital Watermark for Printing –Evaluations of Invisibility and Restoration– ", in Japanese, Proceeding of the 113th Imaging Conference JAPAN 2014, pg.111-114 (2014)

Biography

Nobuki Nemoto received his B.S. and M.S. in Agriculture from Tokyo University of Agriculture and Technology in 2008 and 2010 respectively. He joined Toshiba Corporation in 2010 and now engages in development of security printing technologies in Power and Industrial Systems Research and Development Center.