A Table-based Ink-reducing Approach with estimating ink limitation of media and Gray Component Replacement for Printing Devices

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Abstract

In recent years color inkjet printers have been developed for home and office use. Color printing is accomplished by providing multiple layers of ink on a medium. However, excessive ink usage has caused problems, for instance, ink bleed, paper cockle, high operation cost, long drying time, slow printing, and so on. Therefore, a need exits to reduce the volume of ink used in printing images and thereby eliminate the foregoing problems. The first step of the proposed method for improving the problems is to estimate ink limitation on a medium by selecting reduced ink peak points which indicate that the top intensity of colorant signals is not the full value due to being reduced. And full ink peak points indicate that the top intensity of colorant signals reserves the full value as 255. To maintain a desired color lightness, chroma and hue value within a predetermined percentage deviation, the color difference of the color between reduced ink peak points and full ink peak points must be less than a predetermined color tolerance. The second step is to refer to the selected reduced ink peak points for determining calibration points for each ink color in the colorant space. The third step is to build a printer look-up table based on these calibration points. The final step is to combine Gray component replacement (GCR) to improve the performance of reducing ink here. Since GCR, a well known process in the printing arts, is also a valid method for reducing ink usage, because it can be used to print a single layer of black ink as a substitute for the combination of equal amounts of cyan, magenta and yellow.

Introduction

The methods of reaching ink reduction in the printing could be roughly classified into several technologies including designs for print heads, designs for ink's material, designs for halftoning algorithm using color separation (GCR, UCR), image processing designs (Edge detection, Edge preservation), designs for printer microcontroller, estimating ink limitation of media and maybe combining some of these skills above.

Designs for print heads could resolve some basic ink-consuming problems in the post-printing, for instance, ink evaporation,[1] addresses droplet control aspects about reducing ink evaporation; low voltage contact angle control device; droplet trajectory release modes,[3,4] and belong to designs for ink's material about thermal ink-jet inks having reduced black-to-color and color-to-color bleed,[5-9] and belong to designs for halftoning algorithm to talk about a system for reducing toner or ink consumption in rendering images, in which a transfer function is used to modify halftoning screening of the image to be rendered. A smooth transition from white to the now reduced maximum area coverage, while creating or maintaining the appearance of image uniformity at this reduced maximum area coverage. And the methods of designs for halftoning algorithm can be combined with color separation (GCR, UCR)[10-12] and belong to using color separation (GCR, UCR) to address a four color printing system wherein tone dependent color reduction is to be utilized and the color components for the chromatic printing inks yellow (Y), magenta (M) and cyan (C) are reduced and the amount of black printing ink (K) is increased. The goal is to compensate for the reduction in the chromatic printing inks wherein a nearly total achromatic synthesis is utilized to a gray tone value which corresponds to the full tone of the black printing ink utilized,[13,14] and belong to image processing designs addressing a method for adjusting the dot or pixel density of a digital image which provides a toner or ink saving mode for high resolution printers. The invention is accomplished by generating a mask pattern which is applied to the image data prior to printing to reduce the number of dots actually printed,[15] belongs to designs for printer microcontroller discussing a chart plotter which uses a liquid ink supply (such as an ink jet plotter) the computer program in the plotter microcontroller is modified so that for any one increment of chart movement, each point in the other dimension (i.e., the signal axis) is plotted only once. This conserves ink and also prevents heavy buildup of ink on the chart,[16] exploits estimating ink limitation of media by determining an amount of ink to be used to print a particular color in an inkjet printer in which the colors are measured for a full ink wedge and a reduced ink wedge for a given color. The proposed ink-reducing method doesn't only include estimating ink limitation on a medium by selecting reduced ink peak points depended on that the color difference of the printing color between reduced ink peak points and full ink peak points is less than a predetermined color tolerance to maintain a desired color lightness, chroma and hue value within a predetermined percentage deviation, but it also combines GCR to implement ink reduction.

Estimating Ink Limitation of Media

The software of estimating the amount of ink usage is developed for counting that how many drops on the testing patches are used for each kind of ink, e.g., cyan, magenta, yellow, black respectively. And the algorithm of estimating ink limitation of media is designed by determining the saturation point of color representation when the color values measured by spectrometer in the CIE Lab space are almost the same, e.g., the ΔE_{ab} between two color patches is less than a predetermined color tolerance. To maintain a desired color lightness, chroma and hue value within a predetermined percentage deviation, the limitation of the number of ink drop absorbed for each ink will be obtained in accordance with the analysis.

The processing procedure of the algorithm starts on the patch with the highest intensity, and then others are dealt with in the order of decreasing intensity of the patches. The highest intensity is determined as 255 for C, M, Y, K, respectively. The algorithm of estimating ink limitation of media is described as follows.

$$C_{goal} = \underset{C_i}{Arg}\{\Delta E(C_{\max}, C_i) - T \cong 0\}$$

$$\Delta E(C_{\max}, C_i) = \sqrt{(L_{\max} - L_i)^2 + (a_{\max} - a_i)^2 + (b_{\max} - b_i)^2}$$
$$where \ \ C_{\max} = (L_{\max}, a_{\max}, b_{\max}); C_i = (L_i, a_i, b_i) \qquad (1)$$

Assume that $C_{\max}$ denotes the highest intensity of the patch; C_i denotes others in the order of decreasing the intensity of the patches; C_{goal} denotes the patch on the saturation point of color representation; T denotes a predetermined color tolerance to maintain a desired color lightness, chroma and hue value within a predetermined percentage deviation

Gray Component Replacement

The objective of using Gray Component Replacement (GCR) is to improve the performance of reducing the consumption of the CMY ink in the ink-reducing technology. The GCR indicates that a ratio of black component will be substituted by some ratios of color components (cyan, magenta, and yellow). By the way, the ink coverage is reduced because the equal amount among C, M, and Y ink are replaced with black (K) ink. We use the algorithm to get a RGB to CMYK color conversion table. The goal of using Gray Component Replacement (GCR) is to get a 4D Look-Up Table (LUT) from the 3D LUT after the color matching processing. In the paper, the GCR is exploited into black generation and belongs to the GCR of the dynamic ratio which is defined as follows.

GCR of the dynamic ratio:

*K'=r(C, M, Y) * min(C, M, Y), C'=C-K', M'=M-K', Y'=Y-K'* (2)

where C, M, and Y are the amount of cyan as printing with a RGB to CMY color conversion table, K' is the amount of black instead of CMY, The C', M' and Y' are the respective amount of cyan, magenta and yellow subtracting K' from original C, M and Y, and r is the replaced ratio of GCR.

In Eq. 2, the minimum among C, M, and Y must be determined firstly, and then the minimum subtracts from the original CMY respectively. The replaced ratio of GCR is dynamically dependent on the different optical density of the minimum among C, M, and Y. In this case, the expected objective is that the higher ratio of black component is used instead of CMY components in darker tones in order to make hues pure, to increase the depth in saturation and to reduce the ink consumption, and otherwise the printing task is processed with a RGB to CMY color conversion table in highlight regions in order to avoid artifact appearing due to high contrast between black and highlights.

Experimental Procedure

The experimental digital color palette of estimating ink limitation of media is designed to have seven color bars which have the equal interval among Cyan, Blue, Magenta, Red, Yellow, Green, and Black respectively. And each bar has 33 tonal levels, so the color palette has 162(33x7) patches totally.

Determining Calibration Points for Each Ink Color

The software exploited for counting how many drops on the testing patches is used for each kind of ink, e.g., cyan, magenta, yellow, black respectively. Ink-reducing Estimation Method in Figure 1 also refers to the method of estimating ink limitation of media, and the flowchart of the experiment is shown as Figure 1.

Firstly, the digital color palette is processed with a complementary color conversion from RGB to CMY, i.e., C = 255 - R, M = 255 - G, Y = 255 - B, and the K is used to print the black ink. Secondly, the color conversion palette is then halftoned with software to get halftoned bit-planes' data of each color component. Thirdly, halftoned bit-planes' data will be fed as input to the Histogram Analysis to obtain the number of the drops of each color ink of each patch in the testing palette. In the printing task, the color value in the CIE Lab space of each patch in the testing palette will also be measured by spectrometer, so the relation between the ink drops and color value of each patch can be obtained. The ink limitation of each ink on the medium will be estimated by Eq. 1, and the ink-reducing rates will also be computed.

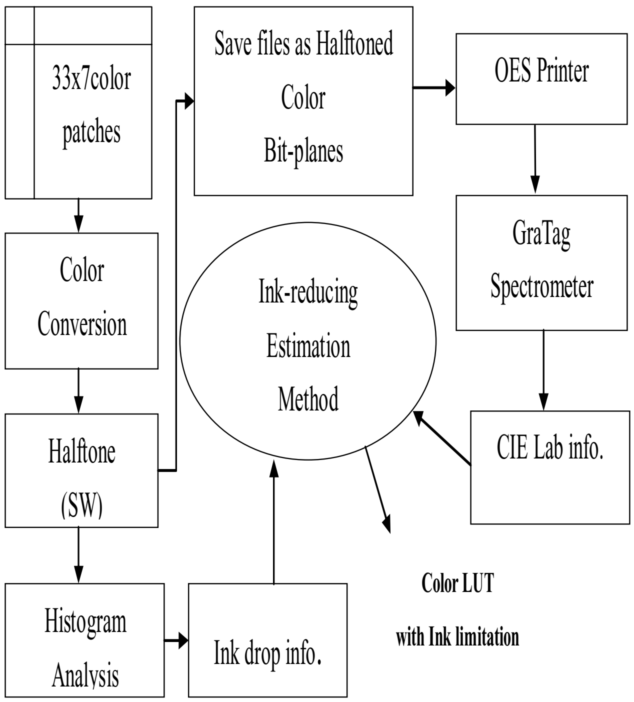

Figure 1. The flowchart of the experiment for estimation ink limitation of media

After finishing the experiment of estimating ink limitation of media, the reduced ink peak points, whose color difference with full ink peak points is less than a predetermined color tolerance, have been gotten. The initial look-up table of color conversion will be derived from the reduced ink peak points. So, the ink used will be saved by avoiding the unnecessary consumption of ink from full ink peak points to the reduced ink peak points.

Build a Printer Look-Up Table Based on These Calibration Points

The experimental method and procedure of building a look-up table for color conversion could refer to Ref. [2], except the initial look-up table with ink limitation is the beginning of 3-D color calibration of RGB to CMY. By way of the 3-D color calibration, the RGB to CMY color conversion table which yields the minimum average color difference between the target palette and the printed palette will be obtained. And then generating a 4-D color conversion table which converts input RGB to CMYK values is based on the results of the RGB to CMY color conversion table (3-D table). In the other words, a 4-D table is derived from the 3-D table by using the GCR algorithm. Some of the black component will replace some CMY components in order to save the ink consumption, to speed up the printing task, to avoid color bleeding, and to increase the depth of the saturated regions.

Experimental Results

The media tested in ink limitation experiments include photo papers and plain papers, while the tested print head is HP C1823D. The predetermined color tolerances (T in Eq.1) assume 4 and 9 in the experiment. The experimental result is shown in Figure 2. The data of ink-reducing rates shown in Figure 2 is estimated only from seven color bars which have the equal interval among Cyan, Blue, Magenta, Red, Yellow, Green, and Black respectively.

From the result shown in Figure 2, it can be found obviously that the ink-reducing rates on plain papers are higher than it on photo papers. The result should infer that photo papers can absorb more ink amount to render more tones of color on the medium. On the contrary, plain papers absorb less ink amount before the phenomenon that the rendered tone caused by absorbed ink almost doesn't change anymore appears. In the case of K, the trend of ink-reducing rates on media is opposite to CMY. It may hint that the media capability of rendering tones of K ink is less than that of CMY ink intrinsically.

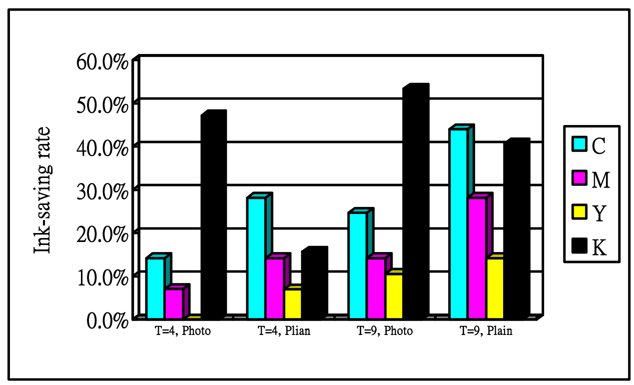

Figure 2. The ink reducing experiment results of different color tolerances and the media

Additionally, it is observed that tones on photo papers do not change over time. It may relate to the fact that photo papers can absorb more K ink amount in the short time, phenomenon that tones almost don't change anymore will appear more easily on photo papers. On the contrary, plain papers absorb less K ink amount in the same time period such that more ink evaporates before being absorbed. So, tones have the chances to render more levels before tones are close to saturation points.

Figure 3 shows ink-reducing rates in different experimental conditions which include different color tolerances in the estimating ink limitation of media, different parameters using in the GCR algorithm. In the figure 3, the data of CMY ink bars are derived form computing the ink-reducing rates of consuming CMY ink. The data of CMYK ink bars are derived form not only computing the ink-reducing rates of consuming CMY ink but also including used K ink. GCR1 and GCR2 infer that the GCR algorithm have two different parameters' groups when doing color separations of CMY to CMYK.

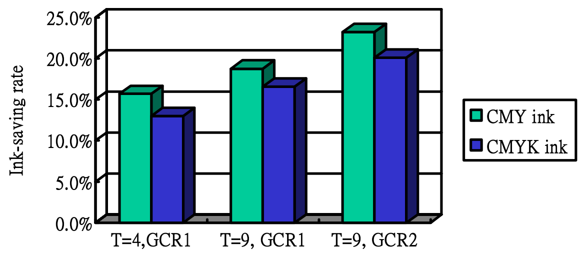

Figure 3.The ink reducing experiment results of different color tolerances and the parameters of the GCR

From two bars in the right hand (T = 4, GCR1 and T = 9, GCR1) shown in Figure 3, it can be seen that the performance of ink reduction is better if the bigger color tolerance could be accepted when estimating ink limitation of media. And from two bars in the left hand (T = 9, GCR1 and T = 9, GCR2) in Figure 3, it can be gathered that the printing with the color conversion of CMY to CMYK can improve the performance of ink reduction further by tuning the parameters of the GCR algorithm.

Conclusion

By the experiments above, the estimating ink limitation of media and Gray Component Replacement indeed can reach the goal of reducing ink usage and maintain the printing quality to an accepted level. Media have different characteristics of absorbing different ink and ink absorbing limitation can be quantitated from ink limitation experiments. Gray Component Replacement also has been verified to improve the performance of reducing the consumption of the CMY ink because K ink is used to replace some CMY ink. So, total ink usage is reduced efficiently.

The proposed algorithms still have some issues to solve. The ink-reducing methods are implemented on the colorant signal domain. Using the technology can't control the number of ink drops precisely in the printing process. In the future research, the objective of the estimating ink limitation of media will try to implement on the domain of ink control to improve the performance of ink reduction and keep the printing quality.

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Biography

Tung-Lin Wu received the B.S. degree in electrical engineering from Tamkang University, Tamshui, Taiwan, in 1999, and received the M.S. degree in communication engineering from Tm,atung University, Taipei, Taiwan, in 2001. He is currently working in Opto-Electronics & Systems Laboratories of Industrial Technology Research Institute (OES/ITRI), Hsinchu, Taiwan, as an associate engineer. His current research areas include color signal processing and image processing coding.