

Uniformity Middle Ware for Photo-Printing

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Abstract

An effective and flexible photo-printing controller for D2T2 (Dye Diffusion Thermal Transfer) and photo inkjet is proposed. The objectives of the present work are to develop the controller architecture using RISC (Reduced Instruction Set Computer) processor and its middle-ware especially used for uniformity correction. In present architecture, the middle-ware provides functional compatibility in the middle layer between hardware and application software.

Introduction

The market for digital cameras is rapidly expanding and the shipment of these cameras has reached 2 million in 1997. Further growth is expected in the market for digital cameras from which images can be transferred to computers for personal and professional use. On the other hand, the hardcopy technologies are shifting from impact printing to non-impact and from monochrome/color to photo-quality printing. These changes reflect the growing availability of digital imaging devices that make it easy to obtain digital-photos without developing process. The silver halide market is also shifting to digitization. Photo-printers for home use and network printing services via the Internet are two main examples of that trend. Photo-printers using D2T2, inkjet, or cycolor are currently available on the market. Previous models based on hardware controller have a limited range of functions; a long lead-time in product development and the difficulty in realizing higher picture quality are also the problems. This paper reports on a photo-printing controller suitable for high-quality photo system, and also focuses on uniformity correction implemented in middle-ware. The controller uses a RISC processor for simple architecture and high-speed middle-ware processing.

Photo-Printing Controller

Figure 1 shows the block diagram of the photo-printing controller. The controller consists of a RISC processor (20 MHz), an interface controller, and an engine controller. The following shows the main functions of the controller.

(1) I/F cont; the physical interface such as Bi-centro, IrDA or USB are controlled and a data-bus is shared.
(2) Middle-ware; the middle-ware operates inside the RISC processor. Figure 2 is a flowchart of this middle-ware. First, the JPEG image data are decoded through format conversion before rotating and scaling. Color transformation using LUT (Look Up Table) is then carried out. At last, filtering and uniformity processing which correct the distortion of the image are executed. Uniformity processing will be described in detail later in this paper.
(3) Engine cont; the engine controller controls the physical interface of the printing head and converts the image data received as multiple levels into bi-level data. When performing continuous-tone printing, the engine controller transfers the bi-level data to the printing head several times on each line and controls the strobe pulse in each transfer. For getting n-level output, it is therefore necessary to transfer the data and control the strobe pulse (n-1) times. The pulse width is changed at each level to preserve the linearity between image data and optical density. Comparative studies using several printing methods show that the VGA controller is up to 20Kgates in hardware size and is between 1 Mbit and 2 Mbit in software size depending on its functions. These requirements can be met in smaller hardware through the middle-ware-based realignment of the image data for the printing head. A configuration without ASIC can be also implemented depending on printing speed. The architecture of simple hardware and high-speed middle-ware processing is flexible and effective.

Uniformity Middle-Ware

In an image printed by the head with many printing elements, distribution of optical density is observed along the main scan direction. Optical density distribution attributable to the printing head often comes from the structural or electrical characteristics of the device itself. Many other factors also interact in a complicated way and develop unevenness of density. Uniformity correction is used for comprehensive correction.

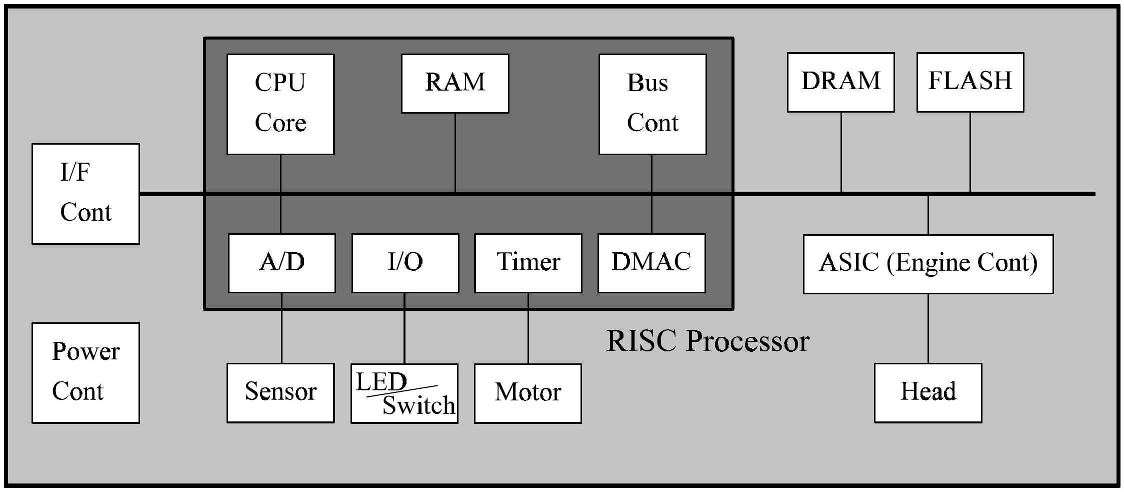

Figure 1. Architecture of Photo Printing Controller

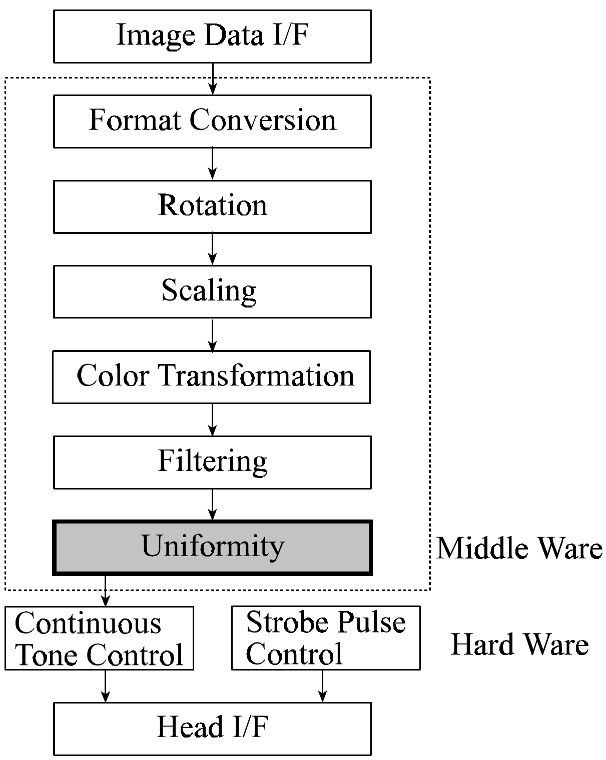

Figure 2. Flow Chart of the Data Processing in Photo Printing Controlller

Uniformity Correction of Structural Distribution

This uniformity correction features the followings.

(1) To reduce the table size for uniformity, the image data is corrected using the characteristic data of density distribution (measured from the density distribution of a printing sample) obtained in advance.

(2) Large bit numbers of the image data are used in order to correct the high-density range with less error.

The procedure is as follows. Di (i indicating pixel position) expresses the optical density of each pixel, and n is the total number of pixels. Average density Dm is then calculated by the following Eq. (1).

$$Dm = \left(\sum_{i=1}^{n} Di \right) / n \qquad (1)$$

The density error Ei of each pixel is calculated as follows.

$$Ei = Di / Dm \qquad (2)$$

Ei in the Eq. (2) can exist at the most in some cases. Considering the table size, a margin of 0.05, for instance, is set for Ei and the whole table is divided into groups. The correction coefficient K is then set for each group so that each pixel has the same density or the average density.

$$K = 1 / Ei \qquad (3)$$

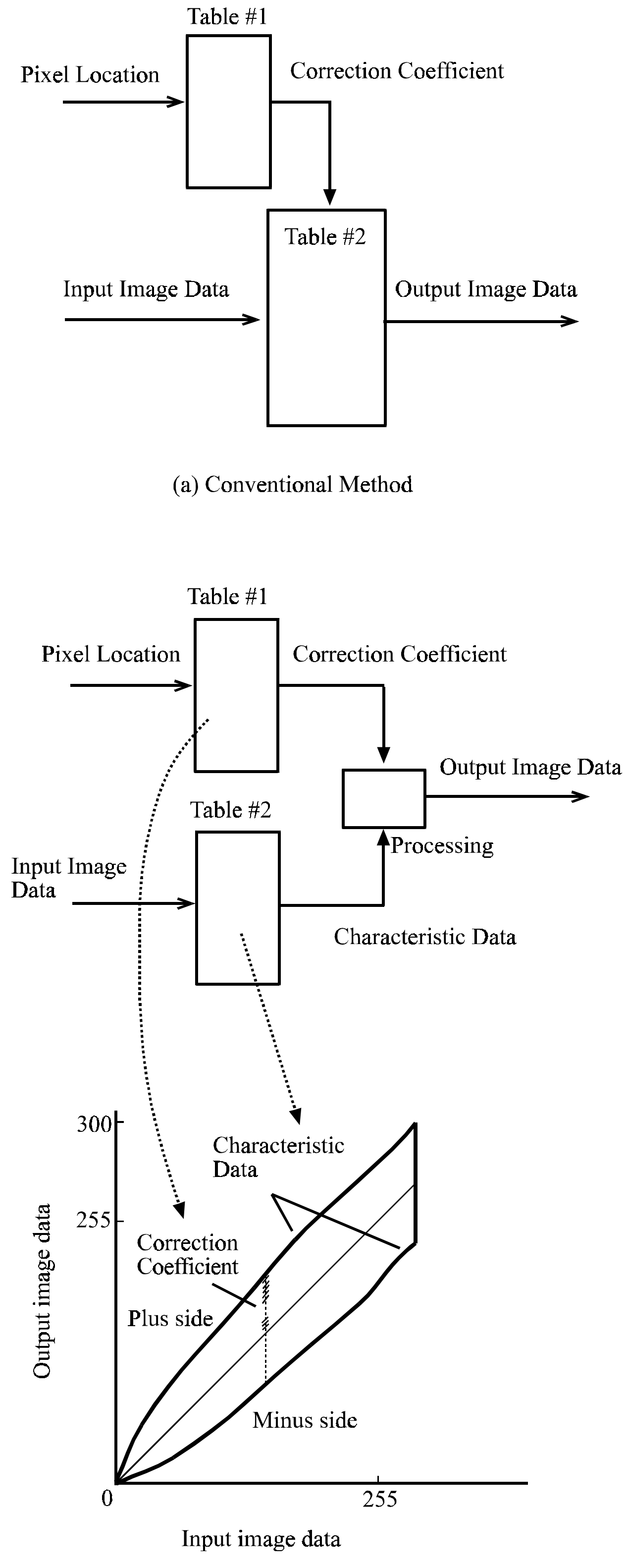

Figure 3. Uniformity Correction

Next, K is obtained at each level through Eq.(3). A graphic expression of the input values of the image data and corrections (output values) shows that they have similar curve. By extracting only the representative characteristic data (correction data of density distribution) and evaluating these data and K of each pixel, the table size can be reduced by less than one-tenth. (The table size shifts from the multiplication of the number of K groups and maximum image data to their sum). To improve the picture quality (especially on the high-density range), an extra bit is added to the number of image data bits after correction. Figure 3 shows this algorithm. With this method, the input image data is converted into one of those inside the area surrounded by the bold line to output the data. The procedure in the middle-ware is as follows.

1. The correction coefficients K divided into 101 groups (50 on the plus side and 50 on the minus side) are read from the table (maximum density distribution: +/-20%, correction accuracy: 0.39%).
2. The input image data, characteristic data and correction coefficients are read and used to carry out the following operation.

$$\text{Output image data} = \text{Input image data} \pm \text{Characteristic data} * K / 256 \qquad (4)$$

Results

The result shows that with the above algorithm, the density distribution can be reduced from a maximum of 20 percent to about 3 percent, significantly improving the picture quality. With this middle-ware, it is possible to use a printing head with relatively large density distribution. Furthermore, the probability of defectives of the printing head has noticeably decreased.

Uniformity Correction of Electric Distribution

Uniformity in this case indicates the correction of voltage fluctuations. In using D2T2 and thermal inkjet models, the range of voltage fluctuations depends on the number of printing elements that are heated at the same time. Letting V be power source voltage, R be common resistor value, r be the resistance of the heating element, and n be the number of elements which are heated simultaneously, power Wn can be calculated by the following Eq.(5).

$$Wn = \left(\frac{V}{r + n * R}\right)^2 * r \qquad (5)$$

When r=2,500 ohms, V=22.7, and R=70 m ohms, there occurs a difference of about 7 percent between 1-pixel printing and 1,280-pixel printing. The strobe pulse width is then corrected as follows,

$$t1 = W_{1280} / Wn * t \qquad (6)$$

where t and t1 are the pulse widths before and after the correction.

The following shows the method of middle-ware processing. To realize high-speed processing, cumulative distribution functions per line are used, and the strobe pulse width at each level is operated. The procedures are as follows.

(1) First, a histogram (Hj) is obtained for the printing line (number of total pixel n) at each level,

$$\begin{aligned} &Hj = 0 \quad (j = 0,1,\text{---},255 \\ &for\ (i = 0,1,\text{---},n\text{-}1) \\ &if\ (Xi = = j) \qquad Hj = Hj + 1 \end{aligned} \tag{7}$$

where j indicates the level and i the ith position of pixel X in the line.

(2) Next, the cumulative distribution function (Pj) is obtained.

$$Pj = n - \sum_{k=1}^{j} Hk \tag{8}$$

(3) Finally, the reduction rate is calculated by the function f (Pj), which is then multiplied by the pulse width.

$$Sj = Sj - Sj * f(Pj) \tag{9}$$

Results

The processing time was measured to be about 3.5 ms. As ordinary printing time per line is 7-15 ms, it is much faster and therefore practical in software processing. Density distribution was also narrowed.

Conclusion

The present architecture has two features as follows:
(1) Hardware size of VGA controller is up to 20Kgates and software size is between 1Mbit and 2Mbit depending on its function.
(2) Uniformity correction is implemented in the middle ware and its algorithm effectively utilizes the characteristic of density irregularity. In addition, the table size used in uniformity correction is below 1/10 as large as one of the conventional method and optical density distribution can be suppressed within 3%. In order for the photo system described in this paper to become widely used, the following three conditions will have to be accomplished in addition to the availability of advanced CPUs and high-speed interfaces:

(a) Low-priced distribution-type computers capable of processing photo images,
(b) access to inexpensive high-quality photo printers, and
(c) greater quantity and variety of application software programs. The age of digital photo printing will arrive when these conditions are satisfied.

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Biography

Keiki Yamada received his B.S. in Information Engineering from the University of Iwate in 1985. Since 1985, he has been working for Mitsubishi Electric Corporation, as an electrical engineer, where he has engaged in research and development of color printers.

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