Image Processing of Digital Minilab System

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Abstract Digitalization has been progressed on Minilab systems in recent years. The advantages of digital Minilab are not only printing from negatives alone, they can also print from a variety of input sources including reversal films and DSC, with greatly improved quality through computation of digital image processing and a wide variety of processing. However, the computation cost for image processing is extremely high, and software processing does not ensure productivity. To solve this problem, we have succeeded in realizing the algorithm with hardware. The present report describes this method.

Key words: Minilab, image processing, hardware

1. Introduction

Digitalization of Minilab systems has been progressed in order to cope with diverse input sources including digital cameras and a wide variety of printing method including super-imposition of images, since difficulty provide high quality image processing by previous analog method. In the meantime, due to the Minilab system is a production machine for photo print, productivity and profitability are important factors. The Minilab system is required to increase productivity and reduce the costs.

Image processing requires a huge amount of image data in order to achieve higher quality than that of conventional printing. As a substantial reduction of product capacity will result if complicated computation is performed to get high quality. So solving this problem is extremely important.

In an effort to find a solution to this problem, we used the hardware for the image-processing algorithm instead of using the software, thereby ensuring compatibility between high image quality and high degree of capability.

The present report introduces an implementation of the image-processing algorithm, mainly configuration of digital Minilab system “Frontier”.

2. System configuration of the digital Minilab system “Frontier”

The digital Minilab system comprises <1> a film scanner where the film is photographed by CCD and is converted into digital data, <2> an
image processor where images are processed to suitable one for printing, <3> an exposure unit to write the image on photo paper by laser, <4> a developer to develop exposed paper, and <5> an operation unit for determining image processing and printing conditions.

The print data from the digital camera or other image files are sent to the image processor via the operation unit <5> (Fig. 1).

The system sequence can be broadly classified into three steps; (a) a pre-scanning step for obtain an image to determine the scanning and image processing conditions, (b) an inspection step for checking and correcting print, and (c) a fine scanning step where a printed image is created according to the result of inspection. In the pre-scanning sequence, one complete film is scanned continuously under fixed scanning condition, thereby obtaining images for all frames. In the setup sequence, as a result of computation is performed based on this all film’s data, setup performance is improved. Scanning conditions for fine scanning and various parameters for image processing are determined by this computation. In the inspection sequence, this image is displayed on the screen and the operator is requested to confirm the image or correct it if required. The result of this manual key correction is reflected in the fine scanning conditions and image on the screen. In the fine scanning sequence, scanning and image processing are carried out according to the image processing parameters determined by computation from setup and inspection. After image processing, the data is sent to the exposure unit where it is exposed on paper by means of a laser. The exposed paper is fed to the developer where it is developed. This sequence of operations is performed by pipeline processing, thereby ensuring a high degree of productivity (Fig. 2).

3. Implementation of image processing algorithm

Being a print product machine, the Minilab system has to be capable of printing 1,000 to 2,000 sheets per hour. The pre-scanning sequence is taken into account, image processing computation must be completed about one second per frame approximately. Moreover, the number of pixels exceeds 6 megabytes in terms of 300 DPI in 4R-size (102 × 152 mm) printing, so image processing must be performed in 500 nanoseconds/pixel or less.

Since we considered it difficult to use software to perform the computation (discussed later) within this time limit, we began to study the use of hardware. However, we use software to obtain the image processing parameters for the setup computation from the following reasons: <1> the computation is processed for not real print images, and <2> this processing is not formalized, hardware is unsuitable for this purpose.

3.1 Basic configuration of image processing hardware

Many ways of using hardware can be considered. Our “Frontier” utilizes a method called pipeline processing. In this method, an image processing circuit is arranged on the image transfer channel. When an image is transferred, image processing is carried out automatically. Although there is a time delay from input to output, productivity does not fall. This method may not satisfy to obtain a print that want immediately, but it is ideal for continuous processing of many prints in a specified time as
in the case of Minilab system (Fig. 3).

With the Frontier, this pipeline system has been used to configure the entire image-processing unit and provide computation for image processing. The image processing parameters are determined by setup computation and pre-set in to the hardware. According to the operation sequence, process is performed automatically merely sending images (Fig. 4).

The other characterized technique of Frontier image processing is conversion of two-dimensional processing into one-dimensional processing. According to this method, the handling as in filtering process for two-dimensional space is divided into two-direction processes (horizontal and vertical) and performed twice in one-dimensional processing. This method results in downscaling of hardware. As for the hardware configuration, an image memory is installed between the two one-dimensional processing circuits. After the image processed in the horizontal direction has been written in the memory, it is read out after 90-degree rotation, and vertical processing is performed (Fig. 5).

Several table used for computation of various corrections, high-speed memory is provided for the LUT (Look-Up Table), and the parameters are set in this memory by software previously. Looking up is made to this table in real time during processing. In addition, the time-sharing method is used to reduce the number of large-scale circuit blocks including the multiplier. This method is used throughout the system.

Even so, the size of the circuit boards will be huge and system feasibility cannot be realized if commercially available ICs alone are used. To solve this problem, ASICs (application specific integrated circuit) are used throughout the image processing hardware.

3.2 Implementation of various types of image processing

3.2.1 Correction of distortion aberration and lateral chromatic aberration of the lens

The Frontier has a built-in function for correcting the distortion aberration and lateral chromatic aberration of less costly plastic lenses having inferior lens performance (Fig. 6). In the practically, this is effective to the Image from a camera which can presume the lens characteristic like single use camera.

For G (green) in this processing, the amount of distortion aberration is calculated from the approximate lens data, and according to this amount of distortion aberration, Zoom magnification is changed for every coordinates at the time of zoom in/out processing.

For R (red) and B (blue), the deviation from G is calculated from the approximate lens data, and zoom in/out processing is carried out as in the case of G. Downscaling of hardware is achieved by combination of zoom in/out and
aberration correction processing as already discussed (Fig. 7).

Originally, lens data used for correction is expressed in two-dimensional higher order terms. By using a one-dimensional higher order expression to approximate this, we created an ASIC for one-dimensional processing. Furthermore, this higher order expression originally required floating-point operations to be performed. To ensure downscaling of hardware, however, only fixed point operations are performed based on the approximation method. In case of Frontier, this processing is performed by two ASICs (a line memory for timing adjustment, an image memory for rotation and image memory control circuit) (Fig. 8).

3.2.2 Correction of peripheral illumination level

A less costly lens has a greatly reduced peripheral illumination level in addition to distortion aberration and lateral chromatic aberration. Consequently, a function for correcting the peripheral illumination level is also provided.

In this processing, a mask image for reversing dimming correction is created from the approximate lens data after being multiplied by a weighting factor. Since this mask image is a low frequency image, it is stored in the memory in compressed form. It is decompressed on a real-time basis when correction is made. After being multiplied by the weighting factor, it is added to the original image (Fig. 9).

This processing is provided by an ASIC, a memory for storing the peripheral darkening mask and SRAMs (static random access memory) for the LUT.

3.2.3 Improvement of facial expression

The major portion of the subject is a human face in many cases. The print yield can be improved by recognizing the face and by correcting the density based on face density. This is especially effective for scenes (e.g. shooting in flash mode), which have not been handled suc-
cessfully by the conventional algorithm. The image obtained in the pre-scanning process is used to extract the face. We have improved accuracy by using a combination of two extraction methods, extraction by color and shape, and extraction by profile. In the case of Frontier, the result of face extraction is also used for local tone control of the face in addition to simple density correction.

To avoid unnatural connection between the extracted face area and other areas, only the ultra-low frequency area is extracted to generate a facemask. This is weighted to control the density of the face in the fine scan image.

To perform this processing on a real-time basis, the facemask is preset in the parameter memory for two-dimensional correction in the hardware. When the image is transferred, this data is read out sequentially and correction is provided. To reduce the cost of this memory and setup time, the facemask is written in compressed form. When it is read out, it is decompressed on a two-dimensional basis (Fig. 10).

This processing is provided by an ASIC, a memory for storing the facemask and SRAMs for the LUT.

### 3.2.4 Processing of Hyper-Sharpness

To emphasize sharpness, USM (un-sharp masking) is generally used. This processing involves emphasizing the grain of the film if degree of emphasis is increased. To solve this problem, we used the characteristics that the grain of the film has high random nature and color correlation in low.

We have separated the spatial frequency zone of the image into three portions. If color correlation in the medium/high frequency area is high, will be the edge of the image and increase the gain in the high frequency area. If it is low, it will be flat part in picture and reduced the gain in the medium frequency area (Fig. 11).

The medium/high frequency components are converted into the luminance component by the Adaptive Matrix (matrix circuit for making the luminance component generation coefficient variable according to the pixel value), and computation is performed (Fig. 12).

To downscale the hardware, this processing is also converted into one-dimensional processing, and is performed twice in the horizontal and vertical directions after rotation in the image memory.

### 3.2.5 Processing of Hyper-Tone

When a scene with wide dynamic range has been photographed, it is difficult to represent both the light and dark portions on prints simultaneously. We have solved this problem by implementing digital dodging (auto mask effect). In Hyper-Tone processing, the ultra-low frequency component of image brightness is extracted, and this value is used to compress the dynamic range by the LUT (Fig. 13).

Since the digital filter used for generation of the ultra-low range frequency component becomes 100 or more taps, it uses an IIR (infinite-duration impulse response) filter in consideration of the hardware scale. To offset the phase distortion of the IIR filter, computation is carried out.

![Fig. 10 Processing for Facial Expression Improvement](image1)

### Color Correlation

<table>
<thead>
<tr>
<th>High Correlation</th>
<th>Edge Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Correlation</td>
<td>Flat Area</td>
</tr>
</tbody>
</table>

![Fig. 11 Hyper-Sharpness Processing](image2)
Fig. 12 Hyper-Sharpness Processing Block Diagram

The luminance component (Y) of medium/high frequency is divided into high frequency and medium frequency, and a gain is controlled by the color correlation value.

Fig. 13 Hyper-Tone Processing

Reference Point YO: Reference Point of Dynamic Range Compression

Dynamic Range compression is applied toward this point.

Fig. 14 Hardware Configuration (Hyper-Tone Processing)

To offset the phase distortion of the IIR filter, the processing direction is reversed by SRAM.

4. Conclusion

A wide variety of image processing functions can be installed in the digital Minilab system, unlike the conventional lab system. For example, you can get high quality images even use a simple camera by using the Frontier's functions for correcting lens distortion aberration, lateral chromatic aberration and the ambient illumination level. As already discussed, image processing not only improves basic image quality, it also enables performance to be maintained. Since we are engaged in equipment development, we will continue further studies in an effort to realize optimum cost performance of the image system as a whole. The Minilab system is a printing machine for production purposes, so any image processing method that ensures the highest image quality cannot ignore printing capacity and price. Therefore, it is important to work in cooperation with those engaged in algorithm development and implementation.

Although not mentioned in this report, there have been a growing number of cases where digital images are directly input due to the widespread use of digital cameras. So services in this field are urgently needed. Thus, one of the biggest problems facing the Minilab system is how to cope with this issue and provide satisfactory services.

References