VLSI Implementation of Adaptive Shading Correction System Supporting Multi-Resolution for Mobile Camera

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ABSTRACT

In this paper, we say the adaptive shading correction system supporting multi-resolution for mobile camera. The shading effect is caused by non-uniform illumination, non-uniform camera sensitivity, or even dirt and dust on glass (lens) surfaces. In general this shading effect is undesirable [1-3]. Eliminating it is frequently necessary for subsequent processing and especially when quantitative microscopy is the fine goal. The proposed system is available on thirty nine kinds of image resolutions scanned by interlaced and progressive type. Moreover, the system is using forty kinds of continuous quadratic equations instead of using the piece-wise linear curve which is composed of multiple line segments. Finally, the system could correct the shading effect without discontinuity in any image resolution.

The proposed system is implemented in VLSI with cell library based on Hynix 0.25 μm CMOS technology.

Key Words : Shading effect, Multi resolution image, Continuous quadratic equation

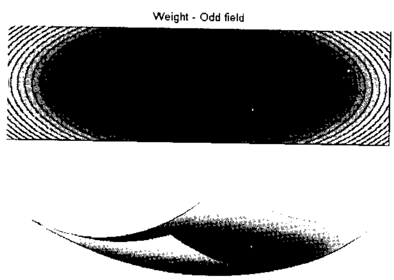
Ⅰ. Introduction

Virtually all imaging systems produce shading effect[4]. By this we mean that if the physical input image $a(x,y)=constant$, then the digital version of the image will not be constant. The source of the shading might be outside the camera such as in the scene illumination or the result of the camera itself where a gain and offset might vary from pixel to pixel. The model for shading is given by:

$$c[m,n] = gain[m,n] \cdot a[m,n] + offset[m,n] \qquad (1)$$

where $a[m,n]$ is the digital image that would have been recorded if there were no shading in the image, that is, $a[m,n]=constant$.

In some cases the image might be bright in the center and decrease in brightness as one goes to the edge of the field-of-view. In other cases the image might be darker on the left side and lighter on the right side[5-6]. In the problems, the proposed system is concentrating on the former case because the edge shaded image is happened most frequently. Moreover, the proposed shading correction method is using retrospective type which can be applied to any image, because the method only uses the information already present in an image[7].



(a) Shading correction weight - Odd field

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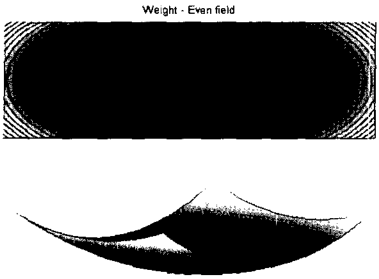


(b) Shading correction weight - Even field

Fig.1 Shading correction weight for edge shaded image

Figure 1 explains the shading correction weight in case of an image using interlaced scan method - Fig.1-(a) odd field and Fig.1-(b) even field.

The rest of the paper is organized as follows. In Section Ⅱ, we show the proposed algorithm for shading correction. Finally, the conclusion is given in Section Ⅲ.

Ⅱ. Proposed algorithm

2.1 Generating Weight to Correct Shading Effect

Figure 2 shows the fundamental theory of shading correction to eliminate the shading effect. As you can see, the system is using the two major terms such as d and d_{max} which are the distance from image center to any input pixel and image corner, respectively.

The correction weight is decided by using the rate between any input pixel's distance(d) and maximum distance(d_{max}) and then, the relationship is shown in Eq.(1).

$$rate = \frac{d}{d_{\max}} \tag{1}$$

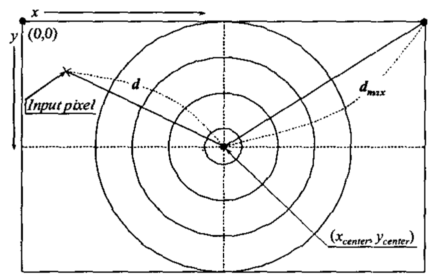


Fig. 2 Fundamental theory of shading correction

Equation(2) is explaining the rate generation process shown in Eq.(1). The terms, (x_{center}, y_{center}), are the center of input image and(x, y) are the corresponding pixel position.

$$rate = \frac{\sqrt{(x_{center} - x)^2 + (y_{center} - y)^2}}{d_{\max}} \tag{2}$$

To enhance system adaptability, the proposed system is available on thirty nine kinds of image resolution shown in Table 1 and image center position(x_{center}, y_{center}) and maximum distance(d_{max}) are different each other along image size. So the proposed system is counting the input image size and finding some parameters such as maximum distance(d_{max}) and center position(x_{center}, y_{center}) by using horizontal sync and vertical sync.

The shading correction weight generation is shown in Eq.(3) and the weight is using nine kinds of $weight_{max}$ to cope with various shading effects.

$$weight = (weitht_{\max} - 1) \times rate^2 + 1 \tag{3}$$

$weight_{max}$ = {1, 1+1/8, 1+2/8, 1+3/8, 1+4/8, 1+5/8, 1+6/8, 1+7/8, 2}

The weight curves calculated by using eight kinds of $weight_{max}$ in Eq.(3) are shown in Fig. 3.

As you can see, the input image is not converted in case that the $weight_{max}$ is '1' because every input color is multiplied by '1.'

Table 1 Available image resolution specification

No.	Image size	No.	Image size	No.	Image size
1	352×288	14	2304×1728	27	2460×1836
2	320×240	15	2272×1704	28	2560×1920
3	640×480	16	2048×1536	29	2592×1944
4	800×600	17	1800×1200	30	2576×1932
5	1024×768	18	1900×1600	31	3008×1960
6	1152×864	19	2048×1536	32	3008×2008
7	1280×1024	20	2967×2232	33	2976×2232
8	1600×1200	21	2016×1512	34	3072×2304
9	1632×1224	22	2282×1712	35	3264×2448
				36	3264×2176
10	1728×1152	23	2272×1704	37	3560×2336
11	1728×1168	24	2304×1728	38	720×488 (NTSC 27MHz)
12	2160×1440	25	2400×1600		
13	1792×1200	26	2240×1680	39	720×576 (PAL 27MHz)

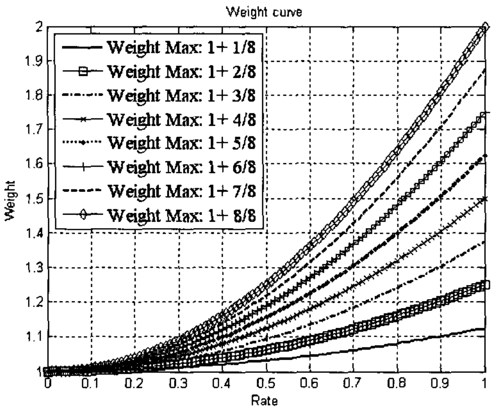


Fig. 3 Weight curves using eight kinds of Weightmax

The Eqs.(2) and (3) are the rate and weight generation method in case of progressive scan, respectively. However, the process in case of interlaced scan should be different with the Eqs. (2) and (3) because interlaced scan displays one frame by using two fields. The Eq.(4) is used when the input image is an odd field.

Figure 4 shows the NTSC interlaced scan which consists of two kinds of field such as odd nd even. Here, image center is on the odd field

$$rate=\frac{\sqrt{(x_{center}-x)^2+\{2\times(y_{center}-y)\}^2}}{d_{\max}} \quad (4)$$

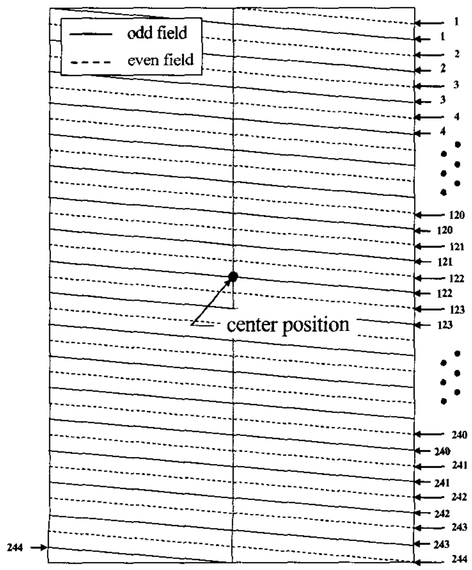


Fig. 4 Interlaced scan - NTSC

a scan line and the even filed lines are shown between odd field scan lines.

The rate generation process of even field is shown in Eqs.(5) and (6) which are corresponding to upper lines (1st line~122nd line) and lower lines(123rd line~244th line) than center position, respectively.

$$rate=\frac{\sqrt{(x_{center}-x)^2+\{2\times(y_{center}-y)-1\}^2}}{d_{\max}} \quad (5)$$

$$rate=\frac{\sqrt{(x_{center}-x)^2+\{2\times(y_{center}-y)+1\}^2}}{d_{\max}} \quad (6)$$

The terms, '+1' and '-1', in Eqs.(5) and (6) imply that the relationship between center and even filed lines in Fig. 4.

2.2 Considering and Applying Weight

Equation 7 shows the weight generation process which is appling five kinds of curvatures to weight.

$$weight=(weight_{max}-1)\times\frac{rate^2+curve\_control\times rate}{curve\_control+1}+1 \quad (7)$$

$$curve\_control=\{0\,,1/8\,,1/4\,,1/2\,,1\}$$

Figure 5 shows the weight curve using five kinds of curvatures in $weight_{max}$, '1+8/8.' As you know, the proposed system is using eight kinds of $weight_{max}$ except $weight_{max}$ is '1.' Therefore, the system is using forty kind of correction curves with $weight_{max}$ and curve_control.

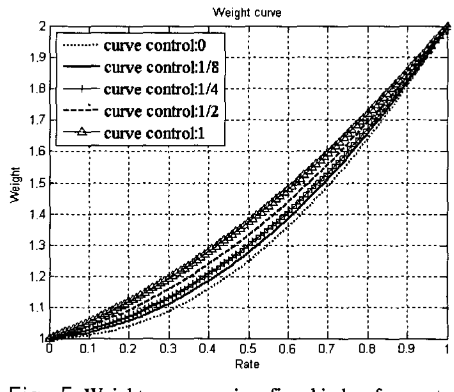


Fig. 5 Weight curves using five kinds of curvatures

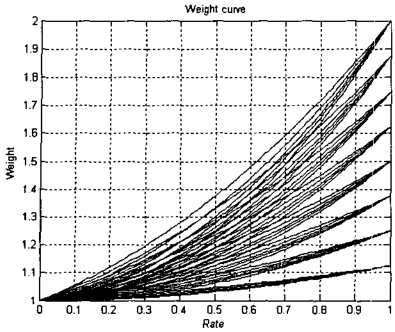
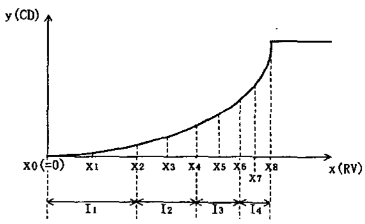


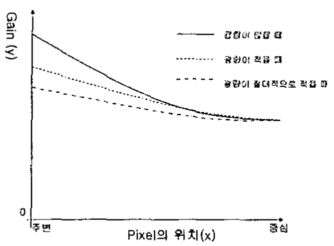
Fig. 6 Forty kinds of weight curves using Fig.3 and Fig.5

Forty kinds of shading correction curves using five kinds of curvatures and eight kinds of $Weight_{max}$ are shown in Fig.6. Therefore, the proposed system could adaptively compensate various images and conditions such as different shading degree and scan type by using correction weight curves in Fig. 6.

Figure 7 shows the contemporary shading correction methods such as piece=wise linear and three kinds of shading correction curves in Fig. 7-(a),(b). The shading correction curve using piece-wise linear method has some discontinuity points. Moreover, it is difficult to compensate various shading effects by using only three correction curves. Here, we can compare proposed system with contemporary shading system. As you can see,



(a) Piece-wise linear method [8]



(b) Three kinds of shading curves [9]

Fig. 7 Contemporary shading correction method

the proposed shading correction curves in Fig. 6 do not have any discontinuity and use forty kinds of correction curves. Also the proposed system is available on thirty nine kinds of resolutions and applicable to any scan type such as interlaced and progressive.

Equations (8)-(10) shows the processes which convert red, green and blue into Y, Cb and Cr.

$$R = 1.164\times(Y-16)+1.596\times(Cr-128) \quad (8)$$

$$G = 1.164\times(Y-16)-0.813\times(Cr-128)-0.392\times(Cb-128) \quad (9)$$

$$B = 1.164\times(Y-16)+2.017\times(Cb-128) \quad (10)$$

By Eqs.(8)-(10), we could know that we should use *(Y-16)*, *(Cb-128)* and *(Cr-128)* to convert red, green and blue on keeping color mixture ratio.

$$Y'_{in}-16=\frac{1}{weight}\times(Y_{in}-16)$$

$$\rightarrow Y'_{in}=\frac{1}{weight}\times(Y_{in}-16)+16 \quad (11)$$

$$Cr'_{in}-128=\frac{1}{weight}\times(Cr_{in}-128)$$

$$\rightarrow Cr'_{in}=\frac{1}{weight}\times(Cr_{in}-128)+128 \quad (12)$$

$$Cb'_{in}-128=\frac{1}{weight}\times(Cb_{in}-128)$$

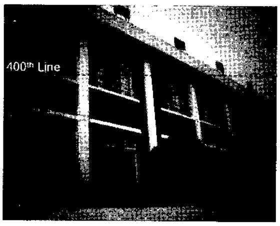
$$\rightarrow Cb'_{in}=\frac{1}{weight}\times(Cb_{in}-128)+128 \quad (13)$$

Equations (11)-(13) show the process that the weight is applied to *(Y-16)*, *(Cb-128)* and *(Cr-128)*.

2.3 Simulation Results

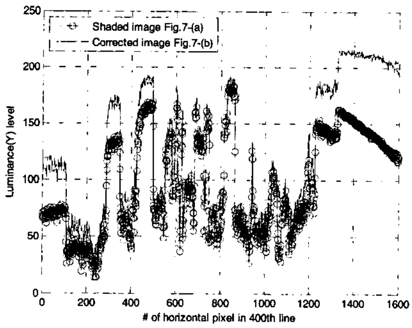
Figure 8 shows the resulting images obtained by using the proposed system in this paper.

As you can see, the border side dark color in Fig.8-(a) is converted into more light in Fig.8-(b). In other words, the shading effect is corrected. Figure 8-(c) illustrates the luminance level comparison between shaded image and corrected image using 400th line in Fig.8-(a),(b). The luminance level difference in center side is very small however that in border side is larger than center like as shading correction curve in Fig.1. And we could not find discoloration or discontinuity in Fig.8-(b). Thereby, the corrected colors can be achieved by using the proposed system without discontinuity and discoloration.



(a) Input image with shading effect

(b) Output image with shading correction processing



(c) Luminance level comparison between shaded image and corrected image using 400th line in Fig.7-(a),(b)

Fig. 8 Input image and simulation result image

2.4 VLSI Architecture Design

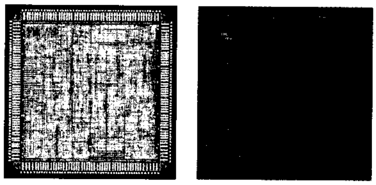
The proposed system is comprised of four major building blocks and designed by using Verilog-HDL models [10]. The input and output signals used in hardware design are under the International Telecommunication Union (ITU) Recommendation BT.601 422 signals for display systems such as TVset, camcoder and so on. It is implemented in VLSIwith cell library based on Hynix 0.25 um CMOS technology. Table 2 shows the characteristicsof shading correction chip and its layout is shown in Fig. 9-(a). The gate counts

Table 2 Synthesis and implementation results

Process	0.25 μm
Gate count	69,139
Chip size	4.7 x 4.7 mm2
Core size	3.8 x 3.8 mm2
I/O pins	144 (In: 88 , Out: 56)
Package type	208 Pin MQFP
Clock rate	50 MHz

are calculated where a 2-input NAND is counted as one gate.

The proposed system is demonstration by using test board with 208 pin socket in Fig. 8-(b) and Agilent technologies 1683A logic analyzer.



(a) Chip Layout (b) Test board with 208 pin socket

Fig. 9 Chip and test board

Ⅲ. Conclusion

In this paper, we proposed the adaptive shading correction system supporting multi-resolution for mobile camera. The proposed system is available on thirty nine kinds of image resolutions scanned by interlaced and progressive type. Moreover, the system is using some continuous quadratic equations instead of using the piece-wise linear curve which is composed of multiple line segments. And then the curves use eight kinds of $weight_{max}$ in Eq.(3) and five kinds of curvature in Eq.(7). In other words, the proposed system corrects the shading effect by using forty kinds of compensation curve without discontinuity like shown in Fig 8.

Therefore, the proposed shading correction system could be applied to the various resolution images and shading environments.

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