Edge enhancement of a sub-pixel rendered image for printing system

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***Abstract*—Recently, sub-pixel rendered filter is often used as a post processing of graphic contents to reduce the jagging artifacts in displays. However, in a printing system, sub-pixel filtered image yields blurring and jagging artifacts due to the difference of displaying method. In order to prevent artifacts, new edge enhancement method is proposed. Edge region of an image is processed by an adaptive intensity mapping function to reduce the mid-range of intensities that make jagging artifacts in half-toning. Then, a color replacement function is applied to reduce the color fringe artifacts. Experimental results show that the proposed algorithm improves the quality of printed sub-pixel rendered image.**

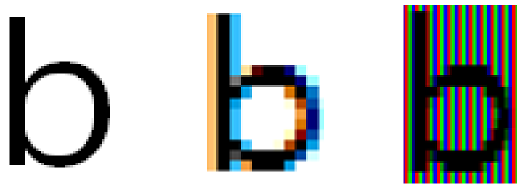
Keywords-component; Sub-pixel rendering, anti-aliased filtering, half-toning.

I. INTRODUCTION

Sub-pixel rendering filter utilizes the pattern of sub-pixels to improve subjective spatial resolution. Treating each RGB sub-pixels as a luminance source, horizontal resolution of displays can be increased by three times. Thus, edges of sub-pixel rendered images look soft [1], [2]. Fig.1 shows the illustrations of sub-pixel rendered fonts. This filtered image is easily observed in web image contents such as banners and logos.

Printing system has several times more resolution than liquid crystal display (LCD). In addition, printing system usually runs in a lower color bit-depth compared to displays; thus color half-toning is required to express continuous tones of images. As half-toning is a process of making dithered pattern for mid-tone, half-toned edges of mid-tone luminance look jaggy. Moreover, fringed color edge could make color jaggy because the color half-tone patterns have different angles for each CMYK colors to prevent moire artifacts [3]. These artifacts are often observed on the edges of sub-pixel rendered images because sub-pixel rendering makes mid-tone pixels and color fringed pixels on the edge of an image.

In previous works, placing dots on edges of an image [4] and changing positions of dots on edges of image [5], [6] are represented to enhance the edges of half-toned image as a post-processing. Learning based half-toning method [7] is proposed to improve the resolution of half-toned image. Previous works enhanced the half-toned edges of image. However, they did not consider the artifacts resulted from a sub-pixel rendering filter. Addressing this problem, we propose new edge enhancement method for sub-pixel rendered images.



(a) (b) (c)

Fig. 1. The example of sub-pixel rendering (a) vector font in a high resolution grid, (b) sub-pixel rendered font, (c) sub-pixel rendered font in a LCD.

II. PROPOSED EDGE ENHANCEMENT ALGORITHM

The proposed enhancement method consists of three functions; Adaptive intensity mapping function, color replacement function, and resolution enhancement.

A. Adaptive Intensity Mapping for Reducing Mid-tone Luminance Pixels

The proposed method uses a region adaptive intensity mapping method to reduce the mid-tone luminance. Luminance of a current pixel is recalculated depending on the distribution of luminance on a window. As the intensity mapping function, sigmoid function is chosen to reduce the mid-tone luminance pixels and it calculates the new luminance with *N*X*N* pixel window including current pixel (*i,j*)

$$w = \frac{1}{1+e^{-(y(i,j)-y_{mean})/tr}} \quad (1)$$

where y_{mean} represents a mean value of current window, and *tr* is a transient parameter of intensity mapping function. Transient parameter is for controlling the sharpness. In this formula, the new intensity ratio ranging from 0 to 1 in the region is found. New intensity value is scaled in the range of min and max luminance value in a window to suppress an abrupt change that may be perceived as noises

$$y'(i,j) = (y_{max} - y_{min}) \times w + y_{min} \quad (2)$$

where y_{max}, y_{min} denote max and min luminance value in a window respectively. For example, in case of processing the region which includes black text and white back ground, mid gray tone is reduced by the mapping formula. Fig. 2 shows the intensity mapping function when y_{max}, $y_{min}$and y_{mean} were 0, 255 and 125 respectively at different transient

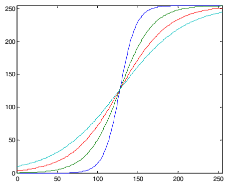


Fig. 2. Intensity mapping function for enhancing sub-pixel rendered image (Y_{min}=0, Y_{max}=255, Y_m=127, tr=2, 4, 8, 16).

values. After filtering, mid-tone luminance resulting from sub-pixel rendering are reduced, and dithered edges are alleviated in a half-toned image as a result.

B. Color Replacement for Reducing Fringed Colors

The proposed method replaces the fringed colors by dominant chrominance to reduce color jagging artifacts. The luminance of main image is darker than that of sub-pixel rendered edges, the chrominance of the darkest luminance pixel in the region is determined as the dominant chrominance, which is expressed as

$$C_D = C(i,j) \text{ when } y(i,j) = y_{min} \in \boldsymbol{W}_y \quad (3)$$

where C_D represents a value of dominant chrominance in a window. Dominant color is found in a UV color space. Then, the chrominance of sub-pixel rendered edge pixels is replaced with the dominant color. This process helps reduce the number of colors in edges. Thus the jagging artifacts from color half-toning of a variety of colors are reduced.

C. Resolution Enhancement for reducing aliasing

After reducing mid-tone, aliasing on the edges are shown. This result is natural because we reduce the mid-tone that helped preventing from aliasing. To compensate this side effect, we process the resultant image by a median filter. Median filter is non-linear filter which replace the current intensity by the medium intensity value on the window. Thus, if the processing region is on the edge of image, the holes that resulted after reducing mid-tone are filled with the intensity of edges. As a result, jagged dots one curve and slope line edges are smoothed without blurring.

III. Experimental Results and Discussions

Computer simulations are conducted to verify performances and merits of the proposed algorithm. As there is no previous research for enhancing sub-pixel rendered image, we compare the results about the before and after images. The text, 'ASG', Britannic Bold font type with size of 10 is typed on a word processor. When the texts are displayed as a raster on a display, they are rendered by a built-in sub-pixel rendering filter. We captured these texts and used them for test images that were processed by the proposed method before printing. Note that the quality of prints may rely upon the property of printing systems. In order to verify the ideal quality of our algorithm, a general color printing system is simulated where the image was resized to fit the resolution of engines in CMYK color space and half-toning to fit the depth of colors was performed.

(a) (b) (c)

Fig. 3. Comparison of results: top: raster image, bottom: half-toned image, (a) Non-processing, (b) Mid-tone reduced and Color replacement, (c) Resolution enhancement of (b).

Fig. 3 (a) shows color half-toned texts without processing of a proposed method. The jagged edges resulted from the half-toning with several color dots can be observed. Fig. 3 (b) shows the filtered texts by the proposed method using a 5x5 window. Fringed colors and mid-tone luminance on the edges are replaced by the color of text in raster image and color half-toned jagging are reduced in half-toned image. Fig. 3 (c) shows that the resolution enhancement processing refines the curve and corner edges more smoothly.

IV. Conclusions

In this paper, new edge enhancement algorithm is proposed to reduce jagging and color fringe artifacts of sub pixel rendered images. The proposed adaptive intensity mapping and color replacement prevents from jagging artifacts by reducing the mid-tone luminance and the fringed colors. Experimental results show that the proposed algorithms reduce the blurring and jagging artifacts on the edges of sub-pixel rendered image. Future research will focus on the performance improvement of the proposed method using sophisticated resolution enhancement techniques without side effects.

References

[1] J. C. Platt, "Optimal filtering for patterned displays," *IEEE Signal processing lett.*, vol. 7, no. 7, pp. 179-181, July, 2000.

[2] Suk-Ju Kang, S. Kim, E. Oh, and W. -W. Song, "Luminance-difference -based adaptive subpixel rendering algorithm for matrix displays," *in Proc. 2012 Digest of Technical Papers Int. Conf. Consumer Electronics*, pp. 733-734, Las Vegas, NV, USA, Jan. 2012.

[3] H. R. Kang, Digital Color Halftoning, SPIE Optical Engineering Press, 1999.

[4] N. J. Kwak, S. J. Choi, and G. S. Lee, "Edge enhancement color halftoning by using human visual characteristics", *International Conference on Hybrid Information Technology(ICHIT'06),* pp. 551-557, Jeju, Korea. Nov. 2006.

[5] J. Feng, P. Li, W. jia, X. qiu, and M. Yuan, "A new edge enhancement on halftone image," *International conference on electric information and control engineering (ICEICE)*, Wuhan, China, pp. 1047-1050, Apr. 2011.

[6] Q. Lin, S. B. M. Bradburn, and B. E. Hoffmann, "Adaptive image resolution enhancement technology," US-patent 6,178,011, Jan. 2001.

[7] H. Y. Kim, "Binary halftone image resolution increasing by decision tree learning," *IEEE Trans. Image processing* vol. 13, no. 8, pp 1136-1146. Aug. 2004.