FLAT-REGION DETECTION AND FALSE CONTOUR REMOVAL IN THE DIGITAL TV DISPLAY

Wonseok Ahn, Member, IEEE, and Jae-Seung Kim, Member, IEEE

Video Lab., A/V Solution Team, Digital Media R&D Center, Samsung Electronics CO., Ltd.

ABSTRACT

Bit-depth reduction in digital displays results in false contours in the image. Moreover some of video enhancement processing in the digital TV display, such as histogram equalization, contrast enhancement, and increasing sharpness, etc., make false contours more visible. Bit-depth reduction comes from various display limitations such as video memory constraints, physical characteristics of the display, display drivers, and coarse MPEG quantization, etc [1]. We present an efficient method for detecting and segmenting flat-region in the image, and a technique for bit-depth extension to effectively remove false contours. We have simulated bit-depth reduction followed by video enhancement processing that cause false contours with various video image sequences including simple patterns. Our result shows that false contours are effectively removed in the flat-region in the image while the sharpness of object edges is preserved.

1. INTRODUCTION

Bit-depth reduction in digital displays including digital TVs results in false contours in the image. Bit-depth reduction comes from various display limitations such as video memory constraints, physical characteristics of the display, display drivers, and coarse MPEG quantization, etc [1]. For example, current LCD Displays are capable of displaying 8-bit gray level at most for each RGB signal. As a consequence of bit-depth reduction, contour-like edges appear in the region where pixel values were smoothly varying originally.

There have been several studies in the literature which addressed techniques for removing false contours. Lee et al. [2] used a dithering technique with gamma correction for plasma display panel (PDP) TVs. Daly and Feng [1] used dithering as a pre-processing and low pass filtering (LPF) as a post-processing to increase bit-depth. This technique may result in trade-off between removing false contours and blurring object edges in the scene. Joy and Xiang [3] addressed a feedback-based quantization technique to detect and minimize false contours in color images.

False contours in an image most likely occur in the region of low frequency and/or smooth gradient. We define these kinds of region as *flat-region* in the image. In flat-region, since pixel values are similar with each other and varying smoothly over relatively large region, false contour looks irritating to human eye. Even some kinds of video enhancement processing in the digital TV, such as histogram equalization, contrast enhancement, increasing sharpness, etc, make false contours more visible.

We present a cost-efficient method for detecting and segmenting flat-region in the image in section 2.1, and a technique for bit-depth extension to effectively remove false contours in section 2.2. In section 3, our experiments and results are presented.

2. PROPOSED METHODS

2.1. Flat-region detection & segmentation

The purpose of flat-region detection and segmentation is to apply bit-depth extension process, which will be explained in Sec. 2.2., only on the region where false contour will occur most likely, so that to leave object edges unprocessed. As a consequence, the common side-effect, blurring the entire image, can be prevented.

The proposed method for detecting flat-region is based on using both the entropy and the second-order statistics of the local region that is centered at the current pixel *(i,j)* (Figure 1). The local entropy $\varepsilon(i,j)$ is calculated by

$$\varepsilon(i,j) = -\sum_{y \in \text{pixel values in block } (i,j)} P_y \log_2 P_y \tag{1}$$

where P_y is the probability of the pixel value y in the current local block. The local deviation $C(i,j)$, which represents local contrast, is computed by

$$C(i,j) = \sum_{(m,n) \in block(i,j)} \frac{\sqrt{(I(m,n) - \bar{I}(i,j))^2}}{M \times N} \tag{2}$$

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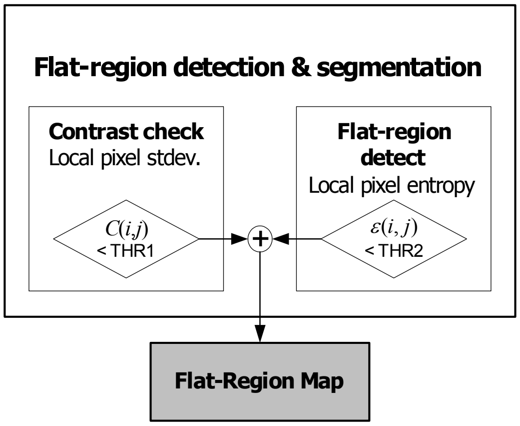


Figure 1. Flat-region detection & segmentation.

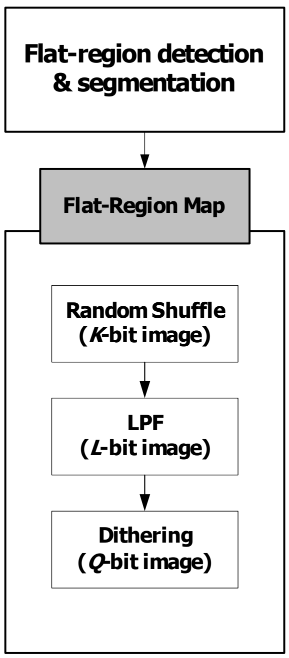


Figure 2. Bit-depth extension in the flat-region map. Generally L-bit $\geq$ Q-bit $\geq$ K-bit in most of the current display.

where *(i,j)* is the coordinate of the current pixel, *(m,n)* is the coordinate of neighboring pixels, I is the pixel value at *(m,n)* and $\bar{I}$ is the mean of pixel values in the local block.

With the local entropy $\varepsilon(i,j)$ and the local deviation $C(i,j)$ computed by (1) and (2) for each pixel, the flat-region map, $MF(i,j)$, is generated as below:

$$MF(i,j) = \begin{cases} 1 & where\ \{(i,j) \mid C(i,j) < THR1\ and\ \varepsilon(i,j) < THR2\} \\ 0 & elsewhere \end{cases} \quad (3)$$

where *THR1* and *THR2* are predefined threshold values for the local deviation and the local entropy respectfully.

In the detection process, the isolated false contour pixels are removed from the false contour region map to avoid the false detection.

2.2. Bit-depth extension for removing false contours

So far the two most common solutions to increase bit-depth have been using dithering technique and LPF. Daly and Feng showed that LPF is not an effective solution for removing false contours as a pre-processing [1].

The proposed methods for bit-depth extension and false contour removal are composed of three consecutive processing blocks, which are Random Shuffler, LPF, and dithering (Figure 2). As mentioned in Sec. 2.1., these processes are performed only in the flat-region detected in the preceding block.

When applying LPF, the gain of LPF coefficients varies according to the proximity of the current pixel location from the *boundary* of the detected false contour region to make smooth transition between the processed region and the unprocessed.

Random Shuffler shuffles pixel locations randomly in a local block as follows:

$$\begin{aligned} &swap\ (I(i,j), I(rand\ (i), rand\ (j)) \\ &\text{and}\ (rand\ (i), rand\ (j)) \in Block\_rand\ (i,j) \end{aligned} \quad (4)$$

where *rand(•)* is a random number index that is generated from the uniform distribution, and *Block_rand(i,j)* is the local block for the current pixel at *(i,j)*.

Random Shuffler removes false contour patterns effectively by sprinkling them over neighboring regions, but makes noise-like pattern appear instead. To remove this pattern, LPF is applied to the region (Figure 2). When we apply LPF to an image, bit-depth may be increased from K-bit to L-bit ($L \geq K$) by selection of bit-resolution of LPF.

To display the output of LPF on the digital displays including digital TVs, we have to re-quantize low pass filtered image into display's own bit-resolution, say Q-bit, which is generally less than that of LPF output, L-bit (Figure 2). This step may produce other false contours. In order to prevent this, dithering technique is employed (Figure 2). We used an error diffusion technique that diffuses error between the output of LPF and quantized image (Q-bit) [4]. The filter used for error diffusion was Floyd and Steinberg's error diffusion filter [5].

3. RESULTS

We used both computer graphic pattern and real video images that contain false contours discernable easily to human eyes.

Figure 3(a) shows an original graphic pattern that has smooth gradient of pixel values. The detected flat-region is white region in Figure 3(b). To simulate the video enhancement process that makes false contour more visible, a simple gray scale mapping function was used as seen in Figure 3(c). Figure 3(d) shows false contours appearing in the image as the result of applying the mapping function shown in Figure 3(c).

The image shown in Figure 4(a) is the low pass filtered image of the image in Figure 3(a). The LPF used was 5-by-5 average filter that was applied over the detected flat-region shown in Figure 3(b). The image in Figure 4(b) is the result of the mapping function. As can be seen in Figure 3(b), false contours still remain.

Figure 5 presents the result of the proposed method discussed in Section 2 for the same image and mapping function above. We can see in Figure 5(b) that false contours are removed noticeably. The LPF used in the proposed method was the same one as used in Figure 4.

Figure 6(a) shows a frame of video sequence of which bit-depth was reduced into 6-bit for the simulation, and contains false contours in the flat-region. The final display bit-depth was set to 8-bit in this simulation. Figure 6(b) demonstrates the detected flat-region by the proposed flat-region detection method. We can see that the detected flat-region contains false contour region but not the object edges. Figure 6(c) is the output of *only* the LPF applied over the flat-region, showing the magnified region of the boxed area in the figure 6(a). Figure 6(d) presents the output of the proposed bit-depth extension method for the same area as figure 6(c), and shows the proposed method removes false contours more effectively than applying the LPF only while the sharpness of the object edge is still preserved.

The plot in figure 7 presents the profile comparison of the luminance signal for the part of the thick line in the image in figure 6. These profiles show that proposed method removed false contour patterns very effectively compared to the LPF method. The LPF method made false contour edge smooth, but cannot remove the local hole-like pattern effectively.

4. CONCLUSIONS

We proposed flat-region detection and bit-depth extension method for false contour removal in the digital TV display.

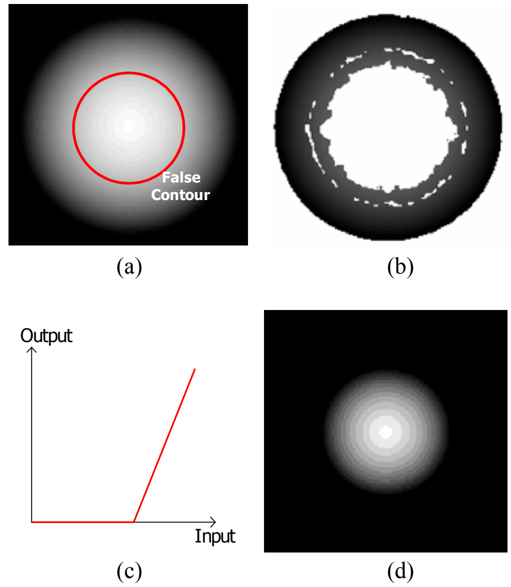


Figure 3. (a) A graphic pattern with smooth gradient, (b) Detected flat-region, (c) Mapping function, and (d) Output of mapping function with false contour appearing

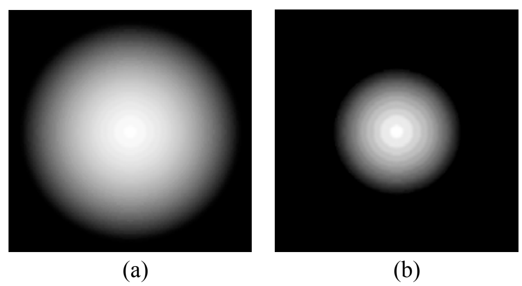


Figure 4. (a) Output of LPF *only* for figure 3(a), and (b) Output of mapping function shown in figure 3(c)

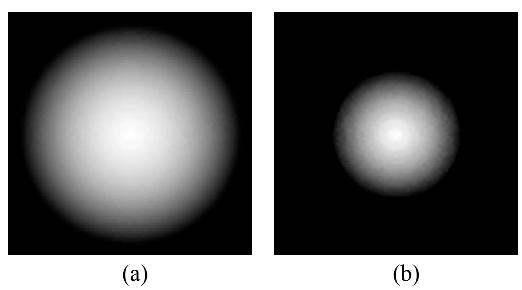
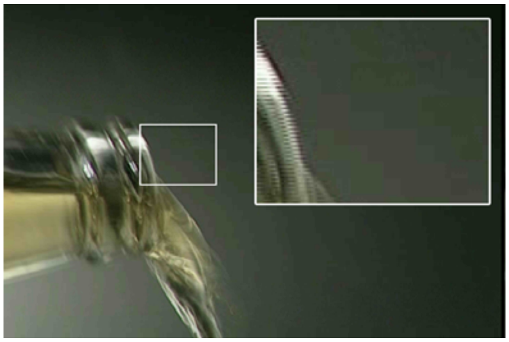


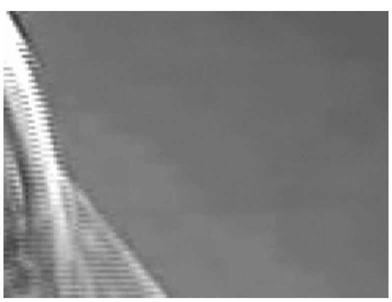
Figure 5. (a) Output of the proposed method, and (b) Output of mapping function shown in figure 3(c)



(a)

(b)

(c)



(d)

Figure 6. (a) A video image of 6-bit depth,
(b) Detected flat-region map of (a),
(c) Result of *only* the LPF applied, and
(d) Result of the proposed method ;
(c) and (d) show the magnified area of the boxed region in (a)

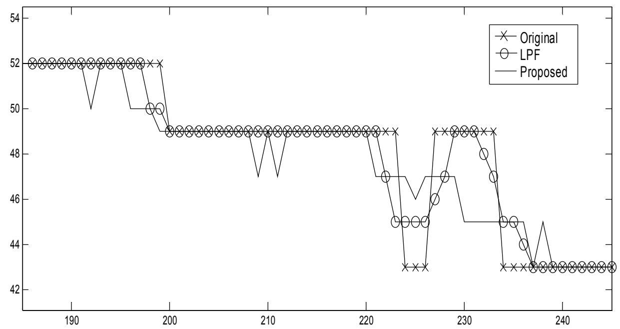


Figure7. The horizontal profile of the luminance signal for the thick line drown over the image in figure 6.

Flat-region detection is done accurately so that the detection map contains the region where false contours may occur most likely, and leaves object edges out.

Following flat-region detection, Random Shuffler, LPF, and dithering processes are performed sequentially over the detected region to increase bit-depth so that false contours are removed effectively.

Both computer graphic patterns and real video images were used in the experiment; bit-depth reduction and a pixel value mapping function were used as a video enhancement process to simulate real digital TV display.

The result shows that the proposed method removes false contours effectively over the detected flat-region while the sharpness of object edges are preserved.

5. REFERENCES

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