Signal-Based Bit Expansion Method for LCDs

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Abstract

In this paper, we describe a signal processing method for upgrading an image quality based on a reduction of contour artifacts. In order to smooth the contour out, some methods have been reported in the image restoration field that had been averaging a pixel code value around the contour. However, these methods have some disadvantages such as hardware complexity and resolution loss. On the contrary, the proposed signal processing method makes it possible to reduce contours without any resolution loss by smaller hardware such as block-based LUTs (look-up tables), since a bit depth of input signal is expanded based on a spatial frequency distribution of the input signal and on the property of the human visual system. By the above features, this method is especially effective, when the bit depth of an input signal is low compared with a bit depth of a display device, or when the display capability of a digital display device improves in the future and became to be able to display more bits than the input signal.

Introduction

According to the recent progress of displays, high definition computer graphic images become to be displayed more precisely and natural images of full of presence are being displayed more naturally.

However, even at the present 8 bits system, some quantization errors are still perceptible as contours as well as displaying a ramp chart at lower bit depth such as 6 bits. The contour at smooth and low key portion of the image is especially visible[1] where the artifact should be expected not to be visible. This is one of the reasons why image quality is deteriorated even at present high-end displays.

Because of that, while most displays have 8 bits capability now, more depth such as 10 or 12 bits is being expected as a future trend.[2]

Preparing the future, in this paper, we will propose a bit depth expansion technology. This technology aims to make the images more natural when the display capability of the display device is improved. The method allows us to improve quality of images expressed with lower bit depth in terms of contour artifacts.

As an example, we will describe a signal processing method to create 8 bits signal from 6 bits signal. We create least 2 bits of 8 bits output signal from 6 bits input signal.

This processing can be utilized at creating 10 bits signal from 8 bits signal. Also this processing can make the low bit depth image such as 4 bits cell phone image more natural at a 8 bits display.

Background

As a method of reducing contour, a filtering method has been reported[3] that takes an average in adjacent dots. Figure 1 shows the comparison of the conventional method and the proposed method. Since only a boundary portion is complemented with conventional method, contour is not visually reduced very well in case of the part whose luminosity be changing loosely. Increasing the tap (number of processing pixels) of filter in order to solve this problem makes hardware complex. And if the kernel length of the filter is not adaptively changed to a spatial frequency distribution of the input signal, the resolution of the image may be deteriorated.

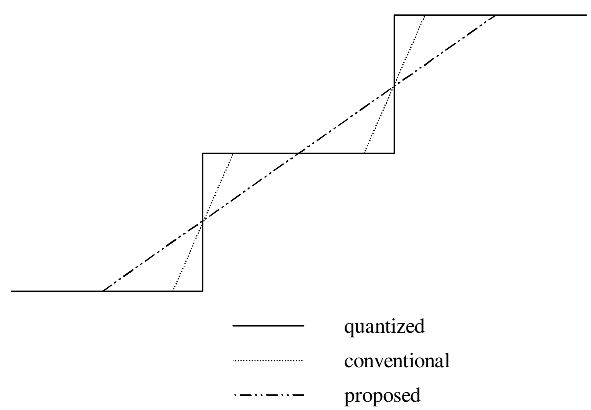


Figure 1. The comparison of the conventional method and proposed method

On the contrary, the proposed signal processing method makes it possible to reduce contours without any resolution loss by smaller hardware such as block-based LUTs, since a bit depth of input signal is expanded based on a spatial frequency distribution of the input signal and on the property of the human visual system. At the following section, we will explain an algorithm of proposed method briefly.

Algorithm

This method is basically divided into two parts. First one is a part that detects features of the input signal. The second one is a part for processing the bit depth expansion based on the features detected.

As for the simple example, we will explain the algorithm based on the following :

1. Screen size: 640(width) and 480(height) pixels
2. Input signal: 6 bits signal
3. Output signal: 8 bits signal by adding least 2 bits onto input 6 bits signal
4. Block width: 64 pixels

Signal Processing

At the following explanation, "i" shows the number that is given in order of the portion that have the same image data continuing at least 2 pixels. "L_i", "S_i", and "W_i" is defined as the image data value, the start pixel position, and the pixel width, of i-th portion respectively. The pixel position of the middle point of "S_i" and "S_i+W_i" is defined as "M_i". "M_i" is the pixel position expressed by the formula "$M_i = S_i + [W_i/2]$" more correctly. [] is the symbol that expresses the greatest integer [x] not greater than x. These parameters are required for signal processing, and are detected by the part that detects the feature of the image signal.

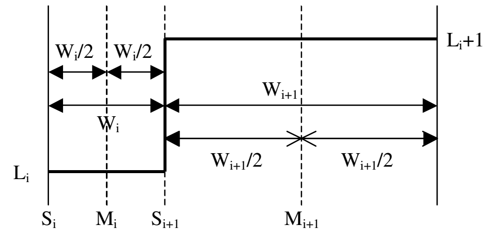
The outline of signal processing is shown in Figure 2. The expansion processing is applied to the signals of the range between "M_i" and "S_{i+1}-1" which have the signal level "$4L_i$", and to the signals between "S_{i+1}" and "M_{i+1}-1" which have the signal level "$4(L_i+1)$". The 6 bits signal levels "L_i" and "L_i+1" are corresponding to "$4L_i$" and "$4(L_i+1)$" in 8 bits expression. So the processing expands the 6 bits signals to the 8 bits signals "$4L_i$", "$4L_i+1$", "$4L_i+2$", and "$4L_i+3$" by adding 2 bits to LSB of each 6 bits signals. Then the Processing can make the image signal smooth.

Before expansion, the image signal level changed discontinuously from the signal level "Li" to "Li+1" (in 6 bits expression) by the shortages of bits as shown in Figure 3. By this processing, the gradation compensation to 8 bits signal is carried out as shown in Figure 2.

The comparison of the conventional method and Signal expansion processing is explained based on Figure 4. If signal expansion processing is started, 8 bits expansion image data "Dj'" will be computed by performing expansion about the 6 bits image data "Dj" of the pixel position "j". This processing is repeated from j = "M_i" to "M_{i+1}-1".

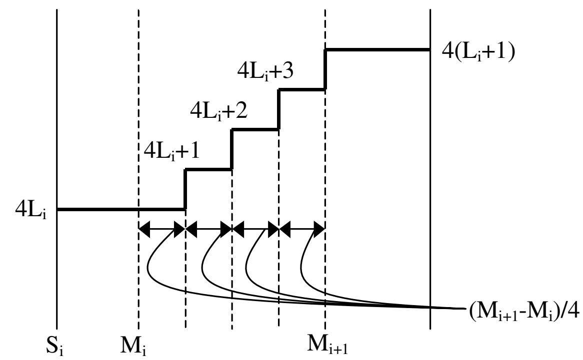
Detection Processing

Figure 5 and 6 is a flow chart which shows the detection algorithm of an image feature. Hereafter, detection processing is explained based on these figures. In the figure, "n" is the number given according to the turn of each pixel position arranged by one line. The image data value is written by D_1, D_2, ---, D_{640} corresponding to n given to each pixel position.



L_i : 6-bits signal value
S_i : start pixel position follows signal value L_i
S_{i+1} : start pixel position follows signal value L_i+1
W_i : pixel width follows signal value L_i
W_{i+1} : pixel width follows signal value L_i+1
$M_i = S_i + [W_i/2]$, $M_{i+1} = S_{i+1} + [W_{i+1}/2]$
[ ] : the symbol of the greatest integer [x] not greater than x

Figure 2. The example of image signal outline before Signal Processing



$4L_i$: 8-bits signal value corresponding to 6-bits signal L_i
S_i : start pixel position follows signal value L_i
W_i : pixel width follows signal value L_i
W_{i+1} : pixel width follows signal value L_i+1
$M_i = S_i + [W_i/2]$, $M_{i+1} = S_{i+1} + [W_{i+1}/2]$
[ ] : the symbol of the greatest integer [x] not greater than x

Figure 3. The example of image signal outline after Signal Processing

Based on Figure 5, a signal value of the attention pixel is first compared with previous and next pixel. By the comparison result, the value of parameters, such as "S_i" and "W_i", is changed or is saved. After repeating these processing from n = 1 to 63, detect whether it is the portion to which the same signal value is following 2 or more pixels and the difference of the signal value is 1 (by 6 bits signal value), i.e., expansion, based on Figure 6. And expansion is performed only when judged as the portion which should carry out expansion.

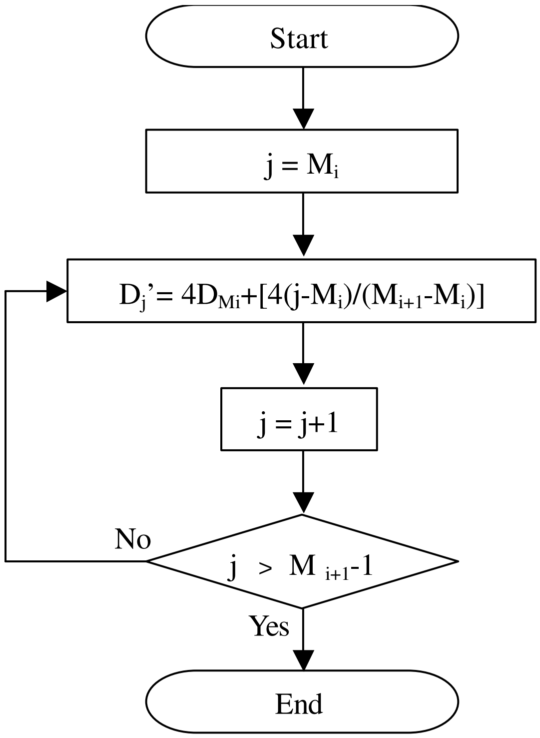


Figure 4. The flow chart explain basic algorithm of Signal Processing

Experiment

We performed a subjective evaluation of the visibility of the contour. We used a 19-inch TFT-LCD as display. This display has 8 bits per channel capability. The signal processing method proposed in this paper was simulated as PC software.

First, the computer graphic image of 6 bits accuracy was displayed on this display. Then, the boundary of each luminosity was clearly seen as contour as shown in Figure 7. Next, when we saw a simulated image that had been generated at 6 bits and processed by the proposed software, we could not see the contour any more as shown in Figure 8. Figure 9 shows the image originally generated at 8 bits accuracy. Even if compared with this original, image quality in terms of the visibility of the contour has been improved as corresponding to 8 bits image.

Consideration

Human vision that observes an image cannot feel contour easily even if luminosity changes by high frequency. But if an image changes in a low cycle, the boundary of the luminosity value tends to be conspicuous to human vision.

By using this characteristic, this method performs expansion not at the higher frequency part of an image signal but only at the low frequency part. So this method can maintain resolution, by leaving an original image in high frequency parts as it is.

Moreover, the fault of the conventional simple filter method that only the boundary is complemented is conquered by this method. So this method is effective to the image that luminosity changes loosely. Although a better effect was not acquired by the filter method unless it changed the filter in adaptation, that adaptation is not necessary in this method. And it can make hardware small by simplifying processing with use of LUT etc. And making width of a processing block into necessary minimum can also reduce memory requirement.

Conclusion

As summarized above, we will propose a bit depth expansion method that can display more bits than that of an input signal. By this processing, the visibility of contour of the 6 bits signal can be reduced as corresponding to that of 8 bits signal.

References

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Biography

Satoshi Ueno is a research member of the LSI Group in SHARP Corporation. He has been with SHARP since 1995 and working for about 4 years in image processing to improve the picture quality of the LCDs. He received B.S. in Mathematics.

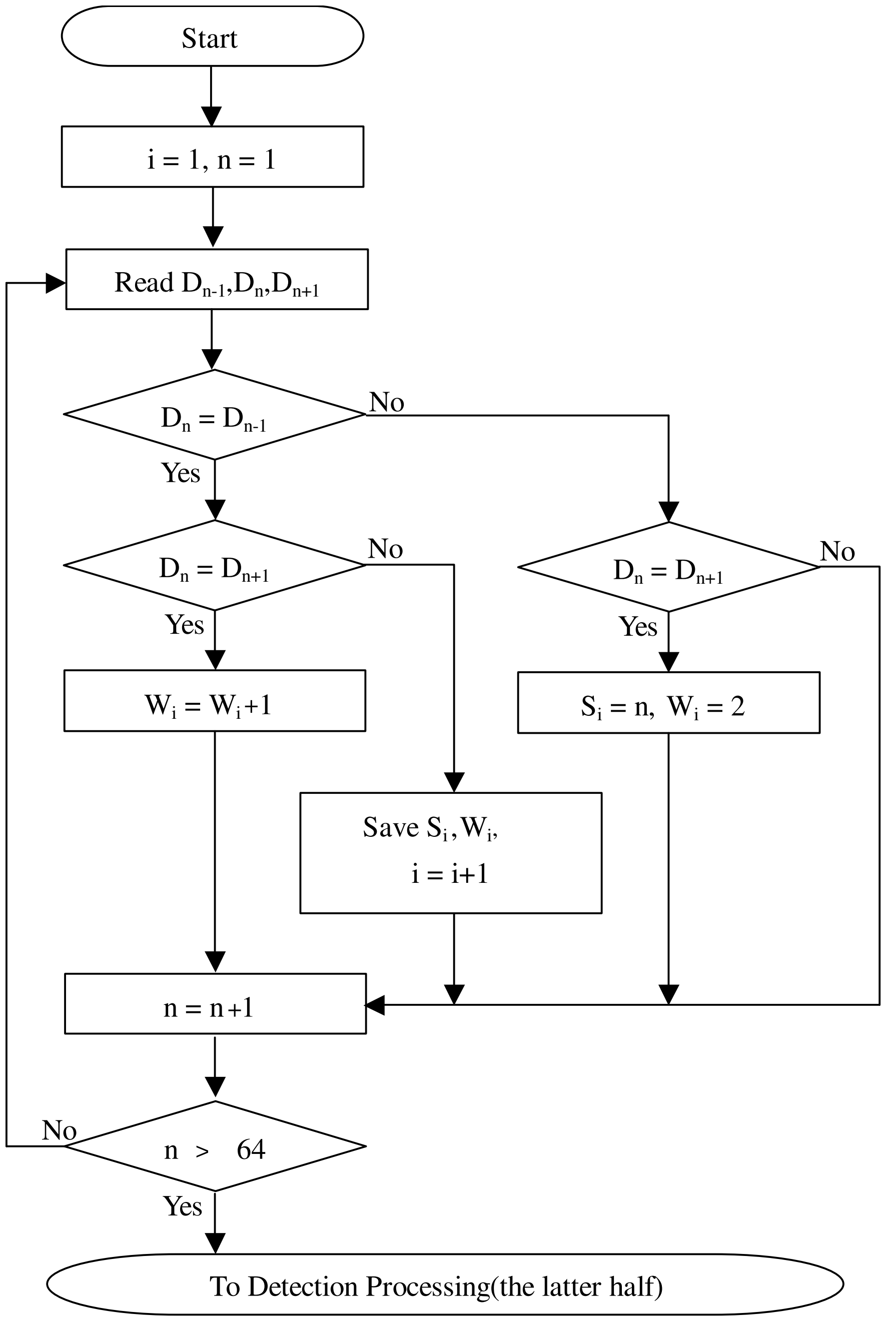

Figure 5. The flow chart explain the first half of basic algorithm of Detection Processing

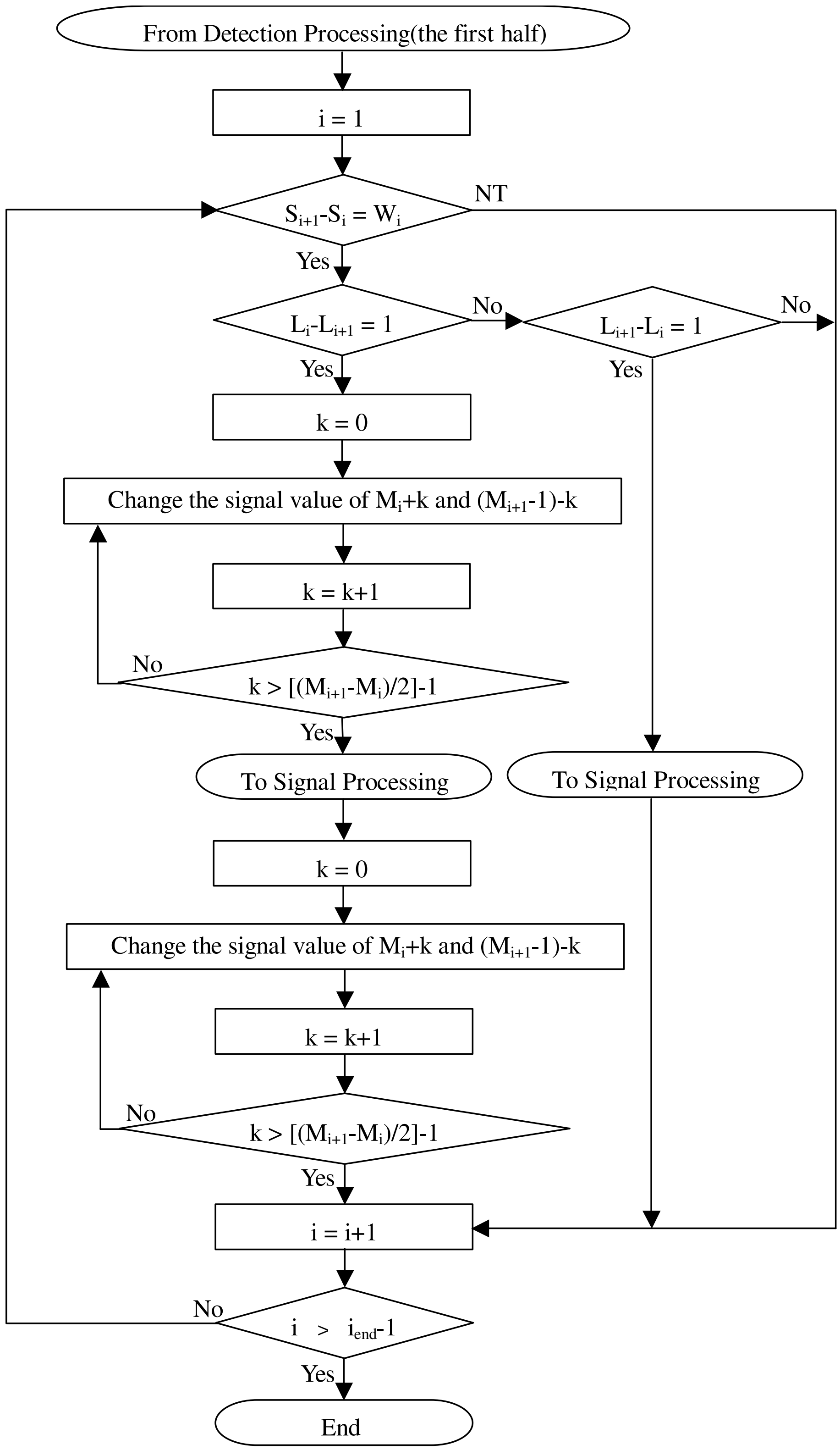

Figure 6. The flow chart explain the latter half of basic algorithm of Detection Processing

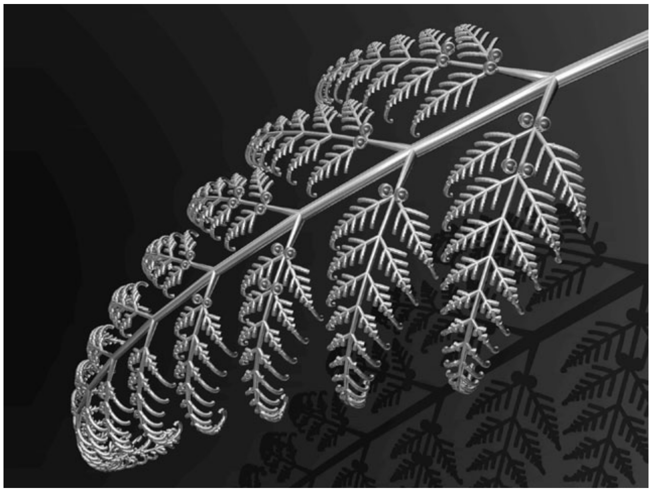

Figure 7. The computer graphic image generated at 6 bits accuracy

Figure 8. The computer graphic image generated at 6 bits accuracy and simulated by the method in this paper

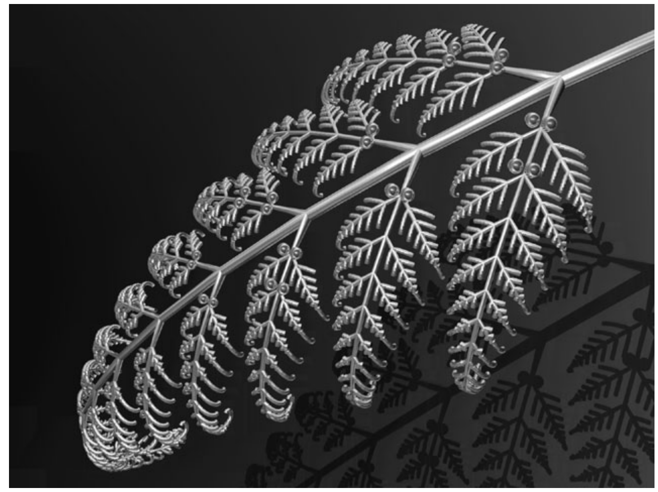

Figure 9. The computer graphic image originally generated at 8 bits accuracy