Transient Improvement Algorithm in Digital Images

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Abstract

Digital images or videos are used in modern digital devices. The resolution of HDTV in digital broadcasting system is higher than that of previous analog systems. Also, mobile phone with 3G can provide images as well as video streaming services in realtime. In these circumstances, the visual quality of images has become an important factor. We can make image clear by transient improvement process that reduces transient in edges.

In this paper, we present an transient improvement algorithm. The proposed algorithm improves edges by making smooth edge to steep edge. Before performing transient improvement algorithm, edge detection algorithm should be operated. Laplacian operator is used in edge detection, and the absolute value of it is used to calculate gain value. Then, local maximum and minimum values are computed to discriminate current pixel value to raise up or pull down. Compensating value that gain value multiplies with the difference between maximum (or minimum) value and current pixel value adds (or subtracts) to current pixel value. That is, improved signal is generated by making the narrow transient of edge. The advantage of proposed algorithm is that it doesn't produce shooting problem like overshoot or undershoot.

1. INTRODUCTION

Digital images or videos are used in modern digital devices. The resolution of HDTV in digital broadcasting system is higher than that of previous analog systems. Also, mobile phone with 3G can provide not only images but also video streaming services in realtime. In these circumstances, the visual quality of images has become an important factor. We can make image clear by transient improvement process that reduces transient in edges.

To enhance the edges, various approaches are introduced. As a conventional work, unsharp masking (UM) method is widely used because it is easy and simple. Extracted high frequency components by using high-pass filter are added to the orignal input image. UM method works well but it produces shooting artifacts and weak against noises. T. Horiuchi et al. proposed an adaptive filtering method which improves edge sharpness and reduces the noises of flat areas [1]. This technique generates luminance slope map which classifies as edge areas and flat areas. Gaussian derivative filter applies to edge sharpness in edge region and SUSAN filter is used to suppress noises in flat region. These two processes are performed adaptively between edge region and flat region according to the luminance slope map.

There is another technique to improve vertical edges in TV signal. Edge is blurred in received images because chrominance signal (U and V) is limited with bandwidth in TV broadcasting system. To recover this problem, "Color Transient Improvement" (CTI) is necessary and it is described in [2][3][4] and [5]. CTI usually restores the high frequency components in the edges by adding or multiplying corrected signal.

In this paper, we present an transient improvement algorithm. The proposed algorithm improves edges by making smooth edge to steep edge. Before performing transient improvement algorithm, edge detection algorithm should be operated. Laplacian operator is used in edge detection, and the absolute value of it is used to calculate gain value. Then, local maximum and minimum values are computed to discriminate current pixel value to raise up or pull down. The intensity of current pixel is added (or subtracted) by compensating value that gain value multiplies with the difference between maximum (or minimum) value and current pixel value. That is, improved signal is generated by making the narrow transient of edge. The advantage of proposed algorithm is that it doesn't produce shooting problem like overshoot or undershoot.

This paper is organized as follows; Section 2 explains transient improvement algorithm; Section 3 presents experimental results; Section 4 describes conclusions.

2. TRANSIENT IMPROVEMENT ALGORITHM

Proposed algorithm consists of 4 steps. At first, transient improvement operating only in the edges requires edge detection algorithm. Also, local maximum and minimum values are searched within the window. These values are used to improve transient by dividing into two part later. Then, transient improvement algorithm is performed to each pixel.

A. Edge detection

Among many edge detection algorithms, we use a simple method. Edge is able to be detected by high-pass filter because edge is regarded as high frequency components. However, it produces problem that noise is treated as an edge. Therefore, we take gaussian low-pass filter to suppress the effect of noise before detecting edges.

Proposed algorithm detects edges using Laplacian operator $Lap(i,j)$ which is second-order derivatives. 2-dimensional convolution operation "**" between input image $f(i,j)$ and Laplacian operator $Lap(i,j)$ as below.

$$f''(i,j) = f(i,j) ** Lap(i,j) \quad (1)$$

Location that the value of Laplacian operation $f''(i,j)$ is higher than threshold is regarded as edge. Threshold which is denoted as th controls edge in the image. As a result, edge region $E(i,j)$ is determined as

$$E(i,j) = \begin{cases} 1, & if \quad f''(i,j) \geqq th \\ 0, & else \end{cases} \quad (2)$$

This edge map $E(i,j)$ is used to operate transient improvement algorithm in the edge region.

B. Transient improvement

Transient improvement algorithm works differently which pixel locates in edge region or not. Proposed algorithm improves edges through reducing transient process. Edge can be sharpened by making the change of intensity to narrow. The smooth change of intensity modifies to steep change is shown as Fig. 1 which is represented in 1-dimension. Solid line is the original edge transition, and dotted line is improved as edge with less transition. Process that makes solid line to dotted line is transient improvement.

For edge sharpness, edge transition should be reduced. The pixel value in the upper part of edge transition should be raised up to maximum value and pixel value in the lower part of it should be down to minimum value. To discriminate whether pixel value locates in the upper part or in lower part in the edge transition, local maximum and minimum values within edge are used. $f_{\max}(i,j)$ and $f_{\min}(i,j)$ denote as local maximum and minimum values by searching neighborhood pixels, and used to calculate the average value M of $f_{\max}(i,j)$ and $f_{\min}(i,j)$. By comparing with $f(i,j)$ and M, edge transition can be classified. When $f(i,j)$ is higher than M, it means $f(i,j)$ exists in the upper part of edge transition. In opposition to this, when $f(i,j)$ is less than M, $f(i,j)$ locates in lower part.

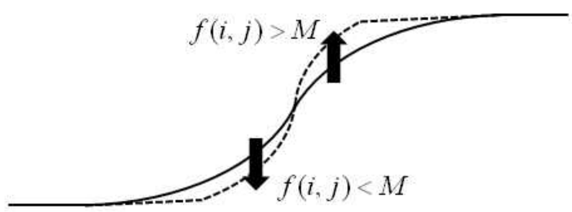

Fig. 1. The change of edge transient.

In order to improve signal, the absolute value $|f''(i,j)|$ of Laplacian filtering result $f''(i,j)$ is used to compute gain value $G(f''(i,j))$ which controls the rate of transient improvement adaptive to local image feature.

$$G(f''(i,j)) = \frac{|f''(i,j)|}{C + r^* |f''(i,j)|} \quad (3)$$

where C is a positive constant number. Also, $r > 1$ is a constant number to control the strength of gain value $G(f''(i,j))$ which is computed according to (3). As r is higher, the sharpness of transient improvement result will be lower. In smooth edge region, the absolute value of second-order derivatives $|f''(i,j)|$ is lower, the change of transient improvement will be lower. In opposition to that, $|f''(i,j)|$ is high in steep edge area, then gain value $G(f''(i,j))$ will be high. The range of gain value $G(f''(i,j))$ is limited between 0 and $1/r$.

As last step for proposed algorithm, equation for calculating the value of improved signal is generated using $f_{\max}(i,j)$ and $f_{\min}(i,j)$. For this, difference between $f_{\max}(i,j)$ and $f(i,j)$ is calculated and used to compensate value toward $f_{\max}(i,j)$. Similarly, difference between $f_{\min}(i,j)$ and $f(i,j)$ is computed to compensate value toward $f_{\min}(i,j)$. Also, gain value $G(f''(i,j))$ adjusts to intensity by multiplication with difference between $f(i,j)$ and $f_{\max}(i,j)$ (or $f_{\min}(i,j)$).

Improved signal $g(i,j)$ can be expressed as below.

$$g(i,j) = \begin{cases} f(i,j) + (f_{\max}(i,j) - f(i,j))^* G(f''(i,j)), \\ \qquad\qquad if \quad f(i,j) > M \\ f(i,j) - (f(i,j) - f_{\min}(i,j))^* G(f''(i,j)), \\ \qquad\qquad if \quad f(i,j) < M \\ f(i,j), \qquad if \quad f(i,j) = M \end{cases} \quad (4)$$

According to the location of pixel value in edge transition, improved signal $g(i,j)$ becomes closer to local maximum or minimum value by transient improvement algorithm. When pixel locates in upper part in edge transition, pixel value moves toward local maximum value. On the other hand, when pixel locates in lower part in edge transition, pixel value moves toward local minimum value. Thus, the slope of pixel value increases in edge transition. Moreover, it doesn't produce shooting artifacts because improved signal cannot be higher than local maximum value or lower than local minimum value.

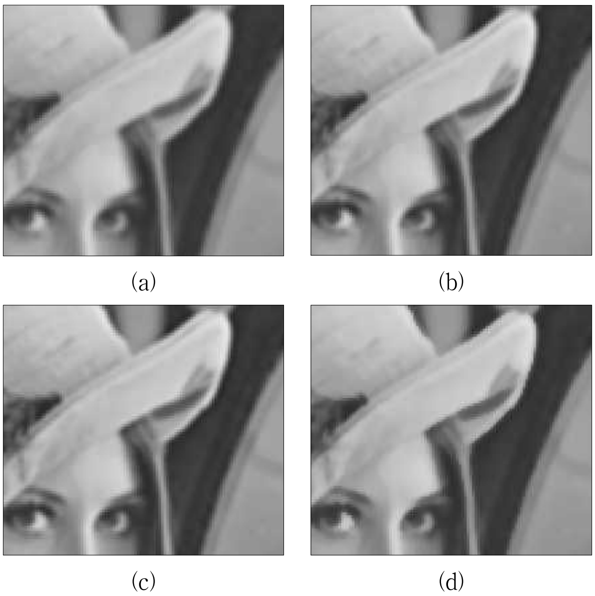

Fig. 2. (a) Original image (blurred). (b) The result of UM. (c) The result of T. Horiuchi et. al. (d) Proposed algorithm.

3. EXPERIMENTAL RESULTS

To test the performance of proposed transient improvement algorithm, blurred image is simulated as an input image. Proposed algorithm is compared with the algorithm of T. Horiuchi et al. [1] and UM.

There are two parameters which affect the result of proposed algorithm. The parameter C to be related to compute gain value and the parameter r to control sharpness exist. C is correlated to $|f''(i,j)|$ in computing gain value and set C between 10 and 30. To compare the result effectively, we make transient improved image look sharp by setting r to be 2.

Fig. 2 shows the transient improvement result of proposed algorithm with other algorithms. The edge of result image is improved from original blurred edge by proposed algorithm. Moreover, algorithm works well without any artifacts like shooting.

4. CONCLUSION

In this paper, transient improvement algorithm is proposed for digital images. Blurred edge is improved sharply by proposed algorithm. We can make smooth edge to steep edge by using gain and difference between current pixel and local maximum or minimum value. Proposed algorithm doesn't produce shooting artifacts and it can control the strength which is related to sharpness of result image with some parameters.

As a future work, we need to study about reducing painting effect which image looks unnatural because of transient improvement process. Also, transient improvement algorithm is weak in detail region. Therefore, we are planning to solve these problems.

ACKNOWLEDGEMENT

This work was supported by Seoul Future Contents Convergence (SFCC) Cluster established by Seoul R&BD Program and the IT R&D program of MKE/MCST/IITA.

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