P-54: Flicker Reducing Backlight Control based on Adaptive Moving Average Filtering

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Abstract

Local dimming of backlights achieves high contrast ratio and low power consumption for LCDs. However, it induces flicker artifacts. The moving average filtering method effectively reduces the flicker artifacts, but causes another problem known as backlight-response-time delaying. This paper presents an adaptive moving average filtering method to deal with above problems. Experimental results show that the proposed method successfully reduces flickers without backlight-response-time-delaying.

1. Introduction

Recently Liquid Crystal Displays (LCDs) have adopted backlight local dimming methods. The methods firstly divide the LCD backlight into smaller blocks. Then the dimming duty of each backlight block is separately determined in proportion to the average picture level (APL) of the block as shown in Figure 1 [1][2][3]. In this way, LCDs achieve high contrast ratio and low power consumption. This method, however, causes another problem. When a glowing light or noise exists in a specific block, the APL of the block is changed continuously as shown in Figure 2(a). This phenomenon makes an unnatural trembling in the block, which is called a flicker artifact [4].

The flicker can be solved by the moving average (MA) filtering method [5]. The output images can be robust to the flicker by taking the average APL value through several consecutive frames as the backlight dimming duty as shown in Figure 2(b). Since this method is simply implemented, it has been generally applied to local dimming LCDs. However, the MA filtering method causes a delaying problem when a scene change occurs as shown in Figure 2(c). This causes an afterimage of the previous frame in the present frame. This is called backlight-response-time delaying.

To overcome the problem, the adaptive IIR filtering method has been proposed by [4]; it changes the backlight rapidly when there is a sharp scene change. However, the backlight can not respond to a scene change existing through lots of frames.

We propose a backlight dimming duty control method using adaptive MA filtering. This method can resolve both the flicker artifact and the delaying problem. The proposed method also determines the tap-length of MA filter separately according to blocks. Therefore, the proposed method can also detect movement existing in only a partial region of a frame that cannot be found by conventional methods.

Figure 1. Example of a local dimming method: (a) Image frame, (b) Locally dimmed backlight for (a), (c) A scene change existing through lots of frames.

Figure 2. (a) APL changes of consecutive frames, (b) MA filtered data for APL changes of consecutive frames with flicker, (c) MA filtered data for APL changes in scene change case.
2. Classification of Movements

The MA filtering is applied to APLs of image frames to reduce the flicker. The backlight-response-time delaying occurs when some kind of changes exist. Therefore, shortening the tap-length of MA filter in case of scene change and lengthening the tap-length otherwise can resolve both the flicker and backlight response time delaying. Movements in scene should be classified in order to adapt the filter length.

When movement occurs in a block, the APL of the block is changed. The figures of change of the APLs through lots of blocks differ depending on the types of movement. Accordingly, we can discern the types of movement: scene change, scene transition, and stationary as shown in Figure 3(a), 3(b) and 3(c), respectively. When the scene changes, the APLs of two adjacent frames have a sharp difference, as shown in Figure 3(a). This type of movement can be easily distinguished from other types of movement. If the APL difference between the blocks at the same position in the two consecutive frames exceeds a pre-defined threshold as shown in Figure 4(a), this case can be determined to be a scene change.

As shown in Figure 3(b) and 3(c), scene transition and stationary cases are hard to discern if only the APL changes of a few consecutive frames are considered. These two cases can be discerned by examining the APL changes among a lot of consecutive frames. The amount of APL changes in the block will exceed a pre-defined threshold as shown in Figure 4(b) if a scene transition occurs. In this case, the tap-length of the MA filter in the block should be reduced not to exceed the threshold so that the backlight-response-time delaying does not happen. On the other hand, the amount of the changes cannot exceed the threshold if no specific movement exists as shown in Figure 4(c), and the tap-length of MA filter has to be kept long to prevent the flicker artifacts.

3. Adaptive MA filter

Let the adjacent frames be indicated with sequential integers, and order the blocks in one frame properly as shown in Figure 5. Then the APL of x-th block in t-th frame \( p_x(t) \) can be expressed as

\[
p_x(t) = \frac{1}{N} \sum \max (r_x(t), g_x(t), b_x(t)),
\]

(1)

where \( r_x(t), g_x(t) \) and \( b_x(t) \) are the red, green, and blue values of the x-th block in t-th frame, respectively. \( N \) is the number of pixels in \( x \). From the equation (1), the amount of APL change of the x-th block between the current frame(t-th frame) and the k-th backward frame((t-k)-th frame) \( R_x(t,k) \) can be expressed as equation (2).

\[
R_x(t,k) = \| p_x(t) - p_x(t-k) \|
\]

(2)

Let define the tap-length of x-th block in t-th frame as \( L_x(t) \). For some value \( k=k_i \), if the \( R_x(t,k) \) exceeds a pre-defined threshold \( T \),
there exists movement between the current frame and the \( k \)-th backward frame in the \( x \)-th block. Therefore, the \( L_x(t) \) should be set shorter than \( k_1 \) so that the backlight response time delaying can be avoided. Similarly, if the \( R_x(t,k) \) does not exceed the pre-defined threshold \( T \) for all values which satisfies \( k \leq k_x \), no effective movement exists between the current frame and the \( k \)-th backward frame in the \( x \)-th block. In this case, the \( L_x(t) \) should be larger than \( k_x \) to reduce the flicker problem.

We suggest a process to determine the \( L_x(t) \) by iteratively comparing the \( R_x(t,k) \) with the pre-defined threshold \( T \). This iteration is processed for all blocks in each frame whenever the tap-length is determined. The movement in the \( t \)-th frame may have high correlation with the movement in the \((t-1)\)-th frame. Hence, the initial \( k \) value of the \( x \)-th block in the \( k \)-th frame is set to the tap-length determined in the \((t-1)\)-th frame. As stated above, the \( R_x(t,k) \) should not exceed the pre-defined threshold \( T \) to avoid backlight response time delaying. In this condition, the \( R_x(t,k) \) has the maximum value to minimize flickers. Therefore, without exceeding the pre-defined threshold \( T \), the \( R_x(t,k) \) is set to maximize the \( L_x(t) \).

This process is expressed in Figure 5. The \( L_x(t) \) obtained by the iteration can be expressed as equation (3).

\[
L_x(t) = \begin{cases} 
\min(L_{\text{max}}, L_x(t-1) + 1) & \text{if } R_x(t,k) \leq T \quad \text{with } k = L_x(t-1) \\
\max(1, k') & \text{if } R_x(t,k) > T \quad \text{with } k = L_x(t-1) 
\end{cases}
\]  

(3)

In equation (3), \( T \) is the pre-defined threshold, \( L_{\text{max}} \) means the maximum tap-length, and \( k' \) is the final value resulting from the above iteration. The threshold \( T \) determines whether movement exists or not, so this value should be sufficiently large to ensure that all APL changes caused by flickers are not regarded as real movement. In addition, the threshold \( T \) should not be so large that any APL change due to real movement is ignored. The maximum tap-length \( L_{\text{max}} \) is used because memory resources are limited, not because the algorithm requires it. \( L_{\text{max}} \) can be set to any value if it is large enough to have sufficient flicker reduction effect.

4. Experimental Results

Many experiments showed that the vibration of APL caused by flicker does not exceed 5 by peak-to-peak value if the whole gray level is expressed from 0 to 255. Hence, the threshold \( T \) is set to 5. The maximum tap-length is set to 16, which is enough to remove flicker problems. Both the proposed method and the conventional MA filtering method are tested for various consecutive image frames. The adaptive variation of tap-length is also shown.

Figure 6 indicates the results which are come from the stationary case. The result from the proposed method is nearly same with the result from the conventional MA filter as shown in Figure 6(a) and 6(b). This means that the proposed filter achieves a good flicker reducing effect.

Figure 7 shows the experimental results with the scene change case. Figure 7(a) and Figure 7(b) indicate that the backlight-response time-delaying which occurs in the result with the conventional MA filter no longer exists in the result with the proposed method. The tap-length of the proposed adaptive MA filter is appropriately reduced to 1 when the scene change occurs, as shown in Figure 7(c).

Finally, the result come from scene transition case is shown in Figure 8. The dimming duty acquired from the proposed method tracks the APL changes faster than the conventional MA filter, as shown in Figure 8(a) and 8(b). The tap-length obtained from the
proposed algorithm is altered from 1 to 16 according to the amount of movement occurring at each moment, as shown in Figure 8(c).

5. Conclusion
This paper has presented an adaptive MA filtering method. The proposed method shortens the tap-length of the filter to prevent backlight-response-time delaying when some kind of movement exists. It lengthens the tap-length of the filter to reduce flickers when no movement is detected. In this way, the proposed method simultaneously solves the flicker artifact and the backlight-response-time delaying. Many experimental results prove that the proposed method shows good performances for both problems.

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7. References