Motion Blur Reduction based on Motion Compensation

Jae-Hyeung Park, Yun-Jae Kim, Minkyu Park, Tadashi Amino, Jaeho Oh, Nam Deog Kim, and Sang Soo Kim
Development Center, LCD Business, SAMSUNG ELECTRONICS, Asan-City, Chungcheongnam-Do, Korea
TEL:82-41-535-5442, e-mail: jh95.park@samsung.com.

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Abstract

Motion-estimation/motion-compensation (ME/MC) provides superior motion picture quality but its huge computation load results in high cost. Impulsive driving is a cost-effective solution but it suffers from large flicker and brightness loss. Motion compensated impulsive driving technology has been developed to achieve high motion picture quality in a cost-effective implementation by combining ME/MC and impulsive driving. The key idea is to apply ME/MC or impulsive driving selectively according to the motion vector distribution of the incoming image sequence. In this paper, the description of the algorithm and the experimental results are provided.

1. Introduction

Motion picture quality is a key issue for LCD-TVs. Motion blur can arise due to slow liquid crystal (LC) response time and the hold-type driving scheme of LCDs.[1] LC response time can be accelerated by using overdrive techniques. Various overdriving techniques and enhancement of the LC material itself have resulted in response times below 8ms for TV applications. Accordingly, LC response time is no longer a significant factor for LCD-TV motion picture quality. The dominant factor for motion picture quality is now, therefore, the LCD's hold-type driving scheme.

Recent approaches to enhance motion picture quality can be classified into two categories: a) High speed driving frame-rate-conversion (FRC) using motion-estimation/motion-compensation (ME/MC), and b) impulsive driving techniques. FRC using ME/MC provides superior performance without any compromise of brightness or flicker [2]. The high cost caused by huge computation load, however, is a drawback of this method. Impulsive driving is a cost-effective solution for improved motion picture quality. Loss of brightness and increased flicker, however, prevent impulsive driving from being applied in premium products. [3]

In this paper, a motion-compensated impulsive driving (MCID) technique is proposed. The basic strategy of the MCID technique is to obtain both high motion picture quality and cost-effectiveness by combining FRC using ME/MC and impulsive driving. The input image sequence is analyzed and ME/MC, impulsive driving, or simple frame doubling is selectively applied. The operating principle and experimental results are described next.

2. Visibility of Motion Picture Quality Enhancement

Although motion picture quality is a key issue for LCD-TV and many algorithms have been developed to improve it, the amount of improvement is highly dependent on the input image contents. In general image sequences containing a complex motion vector field, such as that shown in Fig. 1, enhancement of motion picture quality is nearly imperceptible. One reason for this is that the human eye cannot follow multiple motion vectors when each has different direction and magnitude, therefore the spatio-temporal integration effect (motion blur) is reduced. Another reason is that the input image sequence is already blurred in the image capture process such that motion picture quality enhancing techniques provide less benefit.

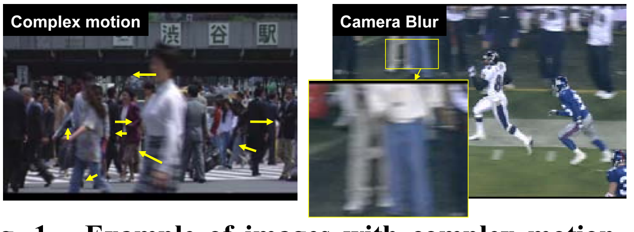


Fig. 1. Example of images with complex motion vectors or camera blur

Enhancement of motion picture quality is most visible in image sequences comprised of global motion or moving objects generated from computer graphics (CG). In global motion sequences, most motion vectors have consistent directions and magnitudes, which makes it easy for the human eye to track the motion such that motion blur and therefore motion blur reduction are readily visible. Also, CG objects such as scrolling tickers have no inherent source-induced blur, which also maximizes the benefit of motion picture quality enhancement.

3. MCID

3.1 Concept

The strategy of MCID is to apply ME/MC or impulsive driving only to image sequences where either technique can have maximum benefit. In general image sequences having a complex motion vector field, neither ME/MC nor impulsive driving is applied and the input image sequence is displayed as-is (or equivalently, using simple frame doubling) on the LCD panel. Figure 2 shows a flow chart of the MCID technique. First, simplified ME is performed on the input image sequence to obtain the coarse motion vector field. Based on the coarse motion vector field, global motion and/or ticker scroll are detected. If the input image sequence is determined to be a global motion sequence, impulsive driving is applied. If ticker scroll is detected in the input image sequence, MC is performed only in the area of the ticker scroll and the simple frame doubling is applied to other areas of the screen. If it is determined that the input image contains neither global motion nor ticker scroll, then frame doubling is applied globally.

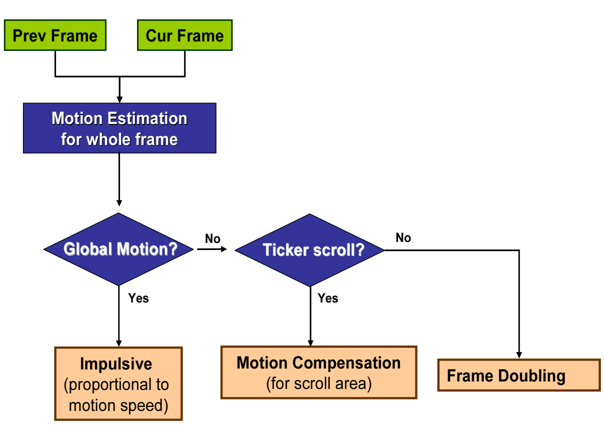
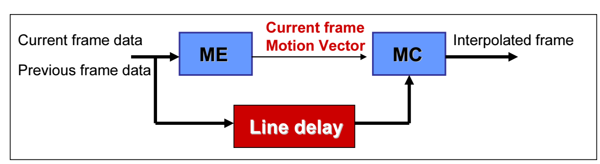


Fig. 2. Flowchart of MCID algorithm

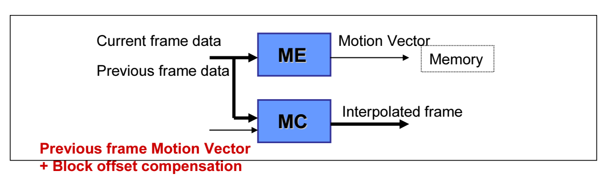
One advantage of MCID is that it can reduce the side effects of ME/MC and impulsive driving. ME/MC occasionally shows some artifacts due to complex motion, but this problem is rarely an issue with MCID since MC is performed only in areas with simple linear motion (such as a scrolling ticker). The side effects of impulsive driving – increased flicker and loss of brightness – are also barely visible with MCID because impulsive driving is applied only to global motion sequences. Note that flicker and/or brightness changes are most visible in still image sequences but are hardly noticeable in moving images.

3.2 ME/MC Simplification

General ME/MC technology is a FRC technique in which complex algorithms must cope with many kinds of motion vector distributions in order to generate artifact-free interpolated frames. As a result of the complexity, system cost is high. However, in MCID, the ME/MC engine can be greatly simplified. The MCID motion estimator generates a coarse motion vector field, which is then used to detect global motion or simple scrolling. The coarse motion vector field is then used to provide simplified motion compensation. Therefore the required density and accuracy of the motion vector field for the MCID ME/MC engine is much simpler compared to the general FRC case. Motion compensation is also simplified for MCID because MC is only applied to simple scrolling motion.



(a) Conventional



(b) MCID

Fig. 3. Removal of line delay

In our implementation, we applied sub-sampling and a reduced vertical search range in the motion estimator. Also, a general FRC engine needs to have large line memory between ME and MC blocks to delay the current and previous frame data by the amount of the ME processing time. The fundamental reason is that the current frame motion vector which is the result of ME block is required for the MC block to deal complex motions. However, as shown in Fig. 3, in the case of MCID, we are able to delete line memory by using previous frame motion vectors instead of current frame motion vectors because in the case of simple scrolling motion like ticker scroll, which is only one case in which motion compensation is applied, the motion will be consistent over several frames. Therefore, reliable results were obtained using much simpler hardware.

3.3 Detection Algorithm

In MCID, global motion and ticker scroll are detected based on the motion vector field obtained using the simplified ME. The main parameter considered is spatio-temporal consistency of the motion vectors. Also, ticker scroll areas are typically rectangular, and this fact is used to get reliable results. After horizontal block lines that have consistent motion vectors are identified, neighboring block lines are merged to form a few macro areas having uniform motion vector field. Some geometrical constraints are imposed to these macro blocks and finally the ticker scroll area is defined.

4. Experimental Result

An FPGA board shown in Fig. 4 was developed to prototype the MCID algorithm. Figure 5 shows the result of ME in a global motion sequence. The arrows on the figure represent the detected motion vectors. We can see that the length and the direction of the arrows are consistent across the figure so that global motion is correctly detected.

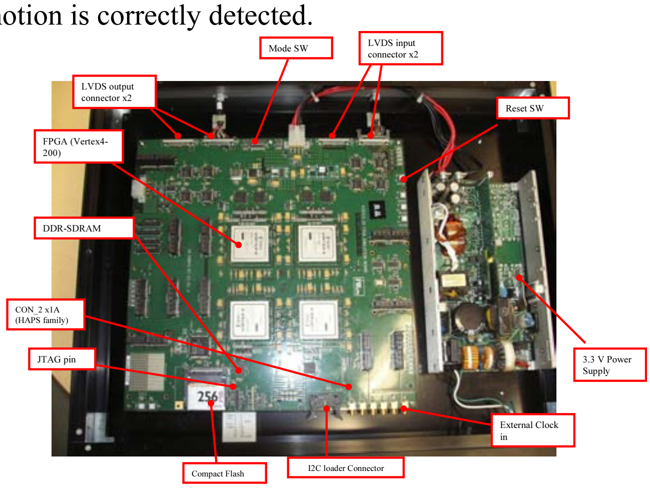


Fig. 4. MCID FPGA board

Figure 6 shows the result of MC for ticker scroll motion. Although previous frame motion vectors are used instead of current frame motion vectors, the figure shows that the quality of the interpolation result is equivalent to MC using current frame motion vectors. The simplification explained above results in an MCID algorithm gate count of less than 2M gates including line memory. This value is significantly smaller than the general ME/MC algorithm which requires over 5M gates.

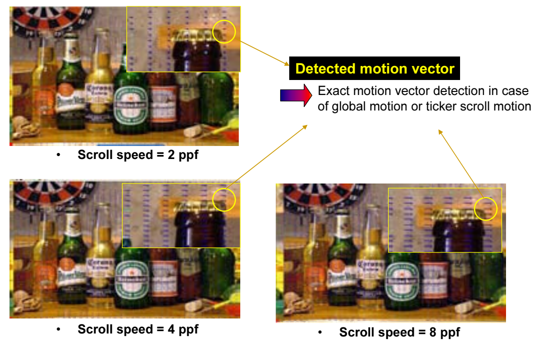
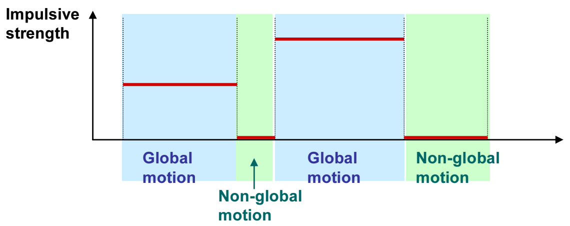


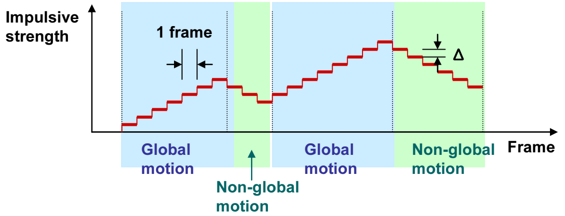
Fig. 5. Result of simplified ME for a global motion sequence

Fig. 6. Result of MC using previous motion vector for ticker scroll sequence

One technical hurdle of MCID is to achieve a seamless transition between impulsive and non-impulsive modes. The brightness change can be alleviated by using quasi-impulsive scanning (QIS) which conserves brightness in impulsive mode. A subtle change of image quality including color characteristics, however, was still noticed between the transitions. In order to minimize this, several smooth transition methods have been investigated. Figure 7 shows two examples of smooth transitions. One method shown in Fig. 7(a) controls the impulsive strength in proportion to the global motion speed. For faster global motion, stronger impulsive driving is applied. In the other method shown in Fig. 7(b), impulsive driving strength is controlled with the step of delta. When the current frame is determined to have global motion, the impulsive strength is raised by delta, and vice versa. In this scheme, the impulsive strength does not change abruptly so that the transition is smooth.



(a) Impulsive strength in proportion to global motion speed



(b) Step-wise change of impulsive strength

Fig. 7. Transition between impulsive and non-impulsive modes

5. Conclusion

MCID provides a cost effective yet high quality solution for motion picture quality enhancement. By adaptively applying impulsive driving, simplified ME/MC, and frame doubling according to the image contents, MCID can improve motion picture quality with reduced side effects and less cost.

6. References

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